

Atlas Application Guide 113

**Xenon-Arc Weathering Testing
of Leisure and Sporting Goods
Selected Testing Standards**

Atlas Material Testing Technology

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Xenon-Arc Weathering of Leisure and Sporting Goods

Selected Testing Standards

1. Introduction

Leisure and Sporting Goods is the collective term for a large diverse product segment. Leisure and Sporting Goods represent a vast field of applications and assorted products as numerous sports have been developed over centuries. Major categories are:

- Clothing and technical textiles
- Equipment and accessories
- Flooring and sports grounds

Some of the products are made of diverse types of textiles tailored to their applications. For example, products such as regular fashion and sporting apparel, tents, backpacks, and more. Others may consist majorly of polymers such as helmets and shoes. Finally, there are products that come with special coatings applied to provide especially attractive looks, aesthetics, protection, or special performances such as water-repellent characteristics. This guide differentiates between products for outdoor and indoor use (**Figure 1**).

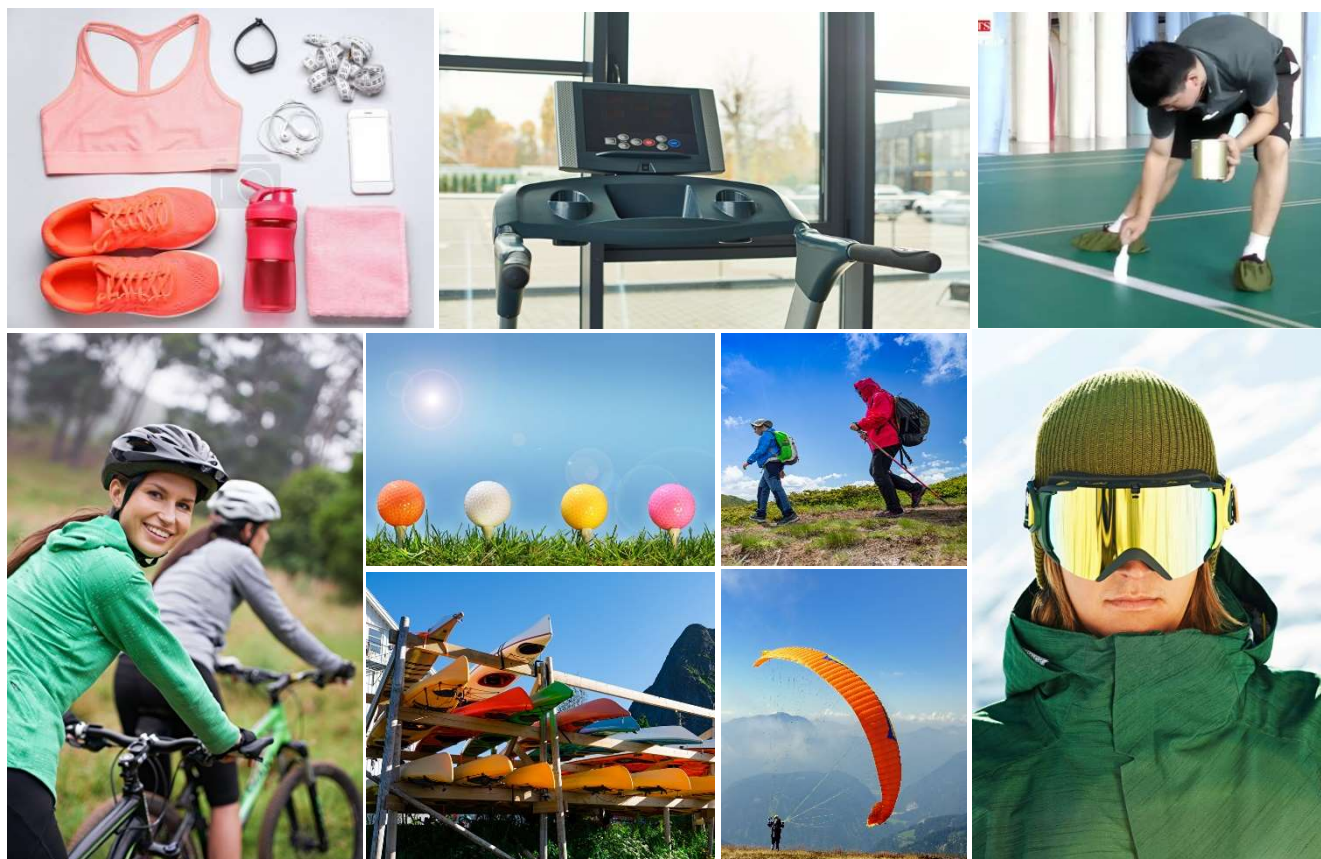


Figure 1: Examples: Leisure and Sporting Goods indoors (top) & outdoors (bottom): using textiles, polymer, and coatings.

The best choice for laboratory accelerated weathering testing are xenon-arc instruments. A major benefit of xenon-arc weathering is excellent solar simulation, both indoors and outdoors, through precision optical filter systems. Each xenon-arc weathering tester – SUNTEST, Xenotest, Ci Weather-Ometer provides full-spectrum coverage, including realistic UV, visible, and IR portions, ensuring accurate testing conditions especially for colored specimens.

Leisure and Sporting Goods which are predominantly used indoors are tested under worst case indoor daylight conditions with specific optical window glass filters installed. Basically, a color fastness test against indoor sunlight.

When we look at Leisure and Sporting Goods for outdoor use, then we use xenon-arc testing with daylight filters and rain cycles. For all outdoor products made of (technical) textiles, polymers, or coatings, the testing is typically not just a check of color fastness against sunlight. Of course, color change goes hand in hand with loss of aesthetic appeal. But very often it is more important to determine their decreasing mechanical strength such as for helmets. Or the change in a coating functionality can be critical, e.g. for hydrophobic coatings used on tents, rain jackets, hiking boots, or water-repellent trousers. Or a coating gloss loss, or delamination.

This xenon-arc weathering testing guide aims at new product development teams and their quality assurance colleagues. It differentiates in the first place between outdoor and indoor used products.

The guide further explains the different weathering testing needs of different Leisure and Sporting Goods depending on their type of materials they use, the application, and their expected durability.

2. Products for Outdoor Use

2.1 Outdoor Leisure and Sporting Goods Made of Textiles

Those products are exposed to outdoor daylight conditions, heat, rain, and dew. For weathering testing, the below-mentioned xenon-arc instruments are equipped with optical daylight filters and additional water spray systems to periodically wet the test specimens.

After 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 where color change is less relevant, mechanical properties such as tensile strength are evaluated. Also important may be the determination of change in functionality - for example, when hydrophobic coatings are used for products such as tents, rain jackets, hiking boots, water-repellent trousers, and many others.

Different Climate Conditions – Different Testing

Our planet encompasses different climate zones, each imposing unique weather stresses on outdoor exposed textiles. Naturally, addressing the significant differences in these climate zones call for distinct test methods. Fortunately, the ISO 105-B10 weathering standard aligns seamlessly with this approach [1]. ISO 105-B10 describes four test methods offering simulations of:

- moderate to warm climates with rain, e.g., Central/East Europe, Scandinavia (Method A)
- moderate to warm climates without rain, e.g., South Europe, South Africa, US (Method B)
- hot semi-tropical climates with rain, e.g., India, South America, SE-Asia, Japan (Method C)
- hot semi-arid climates without rain, e.g., Middle East, Australia, Africa, US (Method D)

Xenon-Arc Instruments Suitable for Textile Weathering

Suitable test equipment for textile weathering are daylight-filtered xenon-arc devices (**Figure 2**), which control:

- Irradiance at 300-400 nm or at 340 nm
- Black Standard (BST) or Black Panel Temperature (BPT)
- Chamber air temperature
- Relative humidity and water spray



Figure 2 (left to right): Xenon-arc instruments meeting ISO 105-B10 and -B04.
Rotating rack: Ci3000 Fade-Ometer®, Ci4400 Weather-Ometer®, Xenotest® 220. Flatbed: SUNTEST® XXL+.

Ci series Weather-Ometer, Xenotest, or SUNTEST XXL+ all meet ISO 105-B10 and 105-B04. Rotating rack instruments excel in providing highly uniform test conditions for flat (up to 10 mm thick) specimens. On the other hand, extra-large flatbed xenon-arc instruments stand out for their spacious test trays, accommodating large, irregularly shaped, or 3-D specimens.

Appropriate quality of the spectrum is achieved by daylight filters that meet the spectral bandpass wavelength requirements for the UV region (**Table 1**). This ensures that the applied spectrum matches natural solar radiation closely enough, according to international reference sun CIE85, Table 4, respectively its successor CIE 241. [2] [3] The irradiance homogeneity over the entire test area shall not exceed $\pm 10\%$ of the mean. If that cannot be achieved, periodic manual repositioning of the test specimens must be done to minimize the effect of variability of irradiance, temperature, and moisture exposure.

Spectral bandpass wavelength λ (nm)	Minimum %	CIE85:1989, Table 4 %	Maximum %
$\lambda < 290$	-	-	0,15
$290 < \lambda \leq 320$	2,6	5,4	7,9
$320 < \lambda \leq 360$	28,2	38,2	39,8
$360 < \lambda \leq 400$	54,2	56,4	67,5

Table 1: Relative spectral irradiance of xenon-arc using daylight filters.

ISO 105-B10 Testing Guidelines

Prior to the release of ISO 105-B10, outdoor textiles have been tested according to the international standard ISO 105-B04, which originated from textile and apparel testing.[4] ISO-105 B04 is still used, however describes only one method which applies a relatively low irradiance level of 42 W/m² and only 1 minute of water spray every half hour. It is proven suitable for textile products (such as apparel) which are not permanently exposed to outdoor weather stress and where the main evaluation criterium is color fastness.

ISO 105-B10 intended for weathering testing of technical textiles, which are permanently exposed to an outdoor environment and often further require mechanical testing such as tensile strength determination. ISO 105-B10 is harmonized with other outdoor test methods for coatings and plastics. ISO 105-B10 describes four different test methods A, B, C, and D, where all tests described are different from the method described in ISO 105-B04.

- The basic cycle of ISO 105-B10, Method A is harmonized with the international weathering standards for plastics (ISO 4892-2) and coatings (ISO 16474-2). Method A uses a higher irradiance of 60 W/m² and a longer wet time of 18 minutes every 2 hours compared to B04, providing a more realistic and harsher test condition.
- Method B is dedicated to textile products that are used outdoor but are protected by rain. Therefore, Method B does avoid water spray.
- Method C is dedicated to products that must withstand very hot (47 °C), humid semi-tropical climates.
- Method D is used to simulate hot (47° C) dry semi-arid desert climates.

Table 2 summarizes the settings of the four test methods.

Test Method	Filter Type	Irradiance (W/m ²)		Surface Temperature (°C)		Chamber Air Temperature (°C)	Relative Humidity (%)	Dry/Wet (min)
		Broad band (300 - 400 nm)	Narrow band (340 nm)	BST	BPT			
ISO 105-B10 (A) moderate, rain	Daylight	60 (preferred)	0,51	65 (preferred)	63	38	50	102/18
ISO 105-B10 (B) moderate, no rain	Daylight	60 (preferred)	0,51	65 (preferred)	63	38	50	-
ISO 105-B10 (C) hot semi-tropical	Daylight	60 (preferred)	0,51	82 (preferred)	77	47	65	90/30
ISO 105-B10 (D) hot semi-arid	Daylight	60	0,51 (preferred)	82 (preferred)	77	47	27	-

Table 2: ISO 105-B10 Weathering Test Methods A - D.

Note 1: AATCC TM 169: Test Method for Weather Resistance of Textiles: Xenon Lamp Exposure, describes similar test conditions.

Note 2: Other irradiance levels than those specified in **Table 2** can be used if agreed between the interested parties.

Type of application	Typical radiant exposure 300-400 nm (MJ/m ²)	Typical spectral radiant exposure 340 nm (kJ/m ² nm)	Typical test duration (h)
Apparel preferably used outdoors under daylight and direct weather conditions, e.g. sportswear, uniforms.	9,5 to 19	81 to 162	44 to 88
Indicative test for apparel, designed for occasional or part-time outdoor use only.	1,7 to 4,8	15 to 40	8 to 22
Long-term exposure for awnings, technical and semi-technical articles, like fishing nets, boat covers, ropes, exposed continuously to outdoor weather conditions.	>57	>485	>264

Table 3: ISO 105-B10 Typical weathering test durations by application.

ISO 105-B10 suggests typical test durations by application, shown in **Table 3**. The test durations in this standard must be considered with caution, since they represent the lowest stress limit for equipment and apparel permanently used outdoors.

Reference Materials

ISO 105-B10 recommends using a reference material of known property change after a certain exposure to check the xenon weathering device for proper performance. It can be a standard reference or an internal reference material. For exposure conditions A and C, Blue Wool References 1 - 8 or L2 - L9 cannot be used because they are not designed for exposure to water spray. Alternatively, the use of the ORWET standard is mentioned: an orange-pigmented coating on aluminum (45 mm x 55 mm), mainly sensitive to irradiation and water.

Summary

The ISO 105-B10 standard outlines four distinct test methods (A, B, C, and D) for accelerated weathering testing of outdoor textiles using daylight-filtered xenon-arc instruments. B10 has been written performance-based allowing all different types of filtered xenon-arc instruments if they can meet all specifications for radiation, temperature, and water. Though the title of B10 states “tests for color fastness” all four methods can also be used to determine ageing behavior of mechanical properties such as the tensile strength. Each method is designed to replicate specific environmental conditions, enabling a comprehensive assessment of color fastness and mechanical aging under different climates - from moderate with or without water sprays, to hot and wet semi-tropical or hot and dry semi-arid.

2.2 Outdoor Leisure and Sporting Goods Made of Polymers

Those products, same as outdoor textiles, are typically exposed to outdoor daylight conditions, heat, rain, and dew. Therefore, for weathering testing, often similar tests to ISO 105-B10 Method A are used. This test method is harmonized with ISO 4892-2 Method A, Plastics - Methods of Exposure to Laboratory Light Sources - Part 2: Xenon-arc Sources. [5]

Alternative cycles and further methods are shown in the American weathering standard ASTM G155: Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials. [6]

All xenon-arc instruments as shown in Figure 2 are suitable while equipped with optical daylight filters and water spray systems to periodically wet the test specimens. Note, every polymer has a certain spectral sensitivity - often a range within the short wavelength UV-A and -B, but also happening in the long wavelength UV-A up to the lower visible wavelength range.[7,8]

The property changes of a polymer-based product caused by the effects of weathering can be:

- Yellowing especially of transparent/white polymers
- Color change
- Loss of physical strength
- Gloss loss caused by micro cracks in the surface
- Embrittlement
- Color fading of dyed/pigmented polymers

There are several ways to protect polymers against the damaging effects of UV radiation and photo-oxidative degradation. Determining the right light protection package (UV absorbers, HALS, antioxidants) for each product is key to avoid premature product failure.

With ISO 4892-2 Method A, we apply regular wet phases (18 minutes) followed by dry phases (102 minutes).

The irradiance at 60 W/m² (at 300 - 400 nm) is on continuously also during the water spray phases, the air temperature at 38°C, and black standard temperature at 65°C all stress parameters are close to natural maxima, so everything is configured to support faster degradation inside the xenon-arc weathering chamber – also known as accelerated weathering - compared to the slower natural process. The test duration depends on the product and its expected service lifetime. The question now is – how much faster (acceleration) is the xenon-arc test and how well does it reproduce the product changes and failures caused by natural weathering (correlation) in a certain region?

Benchmarking, Acceleration, Correlation

To do such a study, we typically compare the accelerated test to a real time exposure at one or more natural benchmark climates such as Miami, Florida (USA) or Sanary sur Mer (France). Miami represents a well-known sub-tropical climate, somewhat representative of other regions like India, South East Asia or South China. Sanary represents a Mediterranean climate, delivering high amounts of radiation and heat – like many other South European regions and represents, in many instances, a European “worst case” climate.

To determine the level of acceleration, you would compare the time required to change the appearance (color) or physical strength of an unstabilized sample to a certain degree – your pass/fail-criteria. Just as an example, you may find that your product reaches the pass/fail-criteria in Miami after 104 days (approximately 2500 hours) and in Sanary after 208 days (approximately 5000 hours). When your product in e.g. a SUNTEST XXL+ just needs 500 hours to reach the same pass/fail criteria, then the acceleration would be 5 for Miami and 10 for Sanary. You can proceed now with stabilized samples and level them out until you have reached a wanted degree of durability – for example show that the stabilized products now exhibit approximately x times higher durability against color or strength change.

How much faster is the accelerated weathering test is one question. How well does the accelerated test correlate to the natural exposure must however also be checked. The correlation of accelerated and natural benchmark weathering is pure statistics. For some cases, it is sufficient to simply look at the ranking correlation. The related statistical method for the ranking correlation of test results is the Spearman rank correlation coefficient. A

reliable and simple method of checking both the strength and direction (positive or negative) of any correlation between two variables - our laboratory test compared to the natural. The coefficient value can lie between -1 and $+1$. The closer to $+1$, the better.

Probably more commonly used is the Pearson correlation coefficient. Same as for Spearman, the closer the Pearson value towards $+1$, the better the correlation. Determined Pearson correlation values >0.7 can be regarded as an indication for sufficient correlation and sort of proof for a well-functioning accelerated weathering test. Pearson correlation coefficients <0.7 however indicate, that further fine-tuning of the accelerated test parameters (e.g., temperature, wet dry phase duration) is required.

2.3 Outdoor Leisure and Sporting Goods with Coatings

Since they are thin film layers, coatings typically respond strongly to water. Of course, the more hydrophilic the stronger. Even when less hydrophilic, coatings tend to take up small amounts of water especially during dew formation overnight. It is because the wet times typically occur then over several hours causing surface expansion during the swelling process. And the reverse when drying up, then coating surfaces contract itself. Note, that rainfalls wet a coating maybe just for 1-2 hours then causing kind of thermal shock depending on the ambient temperature.

We see, the continuous periodic wetting is important, especially when looking at failure modes such as:

- Yellowing
- Cracking
- Gloss loss caused by micro cracks in the surface
- Chalking
- Delamination and flaking

The most common weathering test method for coatings ISO 16474-2 which offers three cycles 1, 2, and 3.[9] While cycle 1 specifies the test conditions for outdoor weathering testing, cycle 2 describes the indoor test conditions for lightfastness testing - indoor conditions such as in private households, gyms, and similar facilities. Cycle 3 addresses the indoor hot lightfastness conditions – a frequently applied test designed to replicate automotive and related extreme interior conditions. ISO 16474-2 cycle 1 is again harmonized with ISO 4892-2 Method A, which means it will use the same regular 18 minutes wet phases followed by 102 minutes dry phases. Should ISO 16474-2 turn out not delivering sufficient water stress and you may observe only poor correlation (see above Benchmarking, Acceleration, Correlation), you should consider using method ASTM D7869 instead. [10]

ASTM D7869 is a weathering test especially developed for transportation coatings (cars, trains, planes). The test adopted the premium daylight filter type Right Light (see Annex A.1 of ASTM D7869). The irradiance level at $0.80 \text{ W/m}^2\text{nm}$ (340 nm) delivers approximately 1.5 times higher irradiance vs ISO 16474-2 testing. Also, the test temperatures are slightly higher. As important as the spectrum and irradiance, the moisture and water spray conditions have also been selected to drive towards highest correlating test results compared to natural weathering.

Table 4 shows ASTM D7869 test conditions. In step 1 the test starts with 3 hours of water spray. This step is critical and delivers much more water compared to ISO 16474-1 cycle 1. Finally, ASTM D7869 is faster than ISO 16474-2.

Step Number	Step Minutes	Function	Irradiance Set Point ¹ @340nm (W/m ² /nm)	Black Panel Temperature Set Point ¹	Chamber Air Temperature Set Point ¹	Relative Humidity Set Point ¹
1	240	dark + spray	-	40°C	40°C	95%
2	30	light	0.40	50°C	42°C	50%
3	270	light	0.80	70°C	50°C	50%
4	30	light	0.40	50°C	42°C	50%
5	150	dark + spray	-	40°C	40°C	95%
6	30	dark + spray	-	40°C	40°C	95%
7	20	light	0.40	50°C	42°C	50%
8	120	light	0.80	70°C	50°C	50%
9	10	dark	-	40°C	40°C	50%
10	Repeat steps 6-9 an additional 3 times (for a total of 24 hours = 1 cycle)					

- Long dark/spray cycles promote high water uptake
- Low irradiance level 0.4 W/m²nm (340 nm) shall simulate dawn conditions
- High irradiance level 0.8 W/m²nm (340 nm) shall simulate intensified peak sun
- Cyclic light/dark phases shall induce thermal shock, mechanical stress

Table 4: ASTM D7869 xenon testing summary

3. Products for Indoor Use

3.1 Indoor Leisure and Sporting Goods Made of Textiles

Indoor products made of textiles are primarily tested against their color fastness to light/sunlight. One of the oldest xenon-arc test methods ISO 105-B02 [11] majorly following the footsteps of Atlas' pioneering xenon lightfastness instrument XENOTEST 150. Fitness and sports apparel, and similar products for major use indoor and typically protected from rain are tested using such test conditions of solar radiation behind window glass. For so called light fastness testing, xenon-arc instruments must use optical window glass filters.

Cover Masks

For most textile color fastness 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. [11,12,13] Some procedures require masks to be exchanged after intermediate evaluations.



Figure 3: Left: ISO 105-B02 Exposure Method 2 cover masks. Center: AATCC cover mask. Right: 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. The American test method AATCC TM16.3 use another Blue Wool scale: the AATCC scale **L2-L9**. Everything worse than Blue Wool **L2** gets a lightfastness rating **L1**.

The Grey Scale is used to visually assess color change. [14,15] 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, and 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.

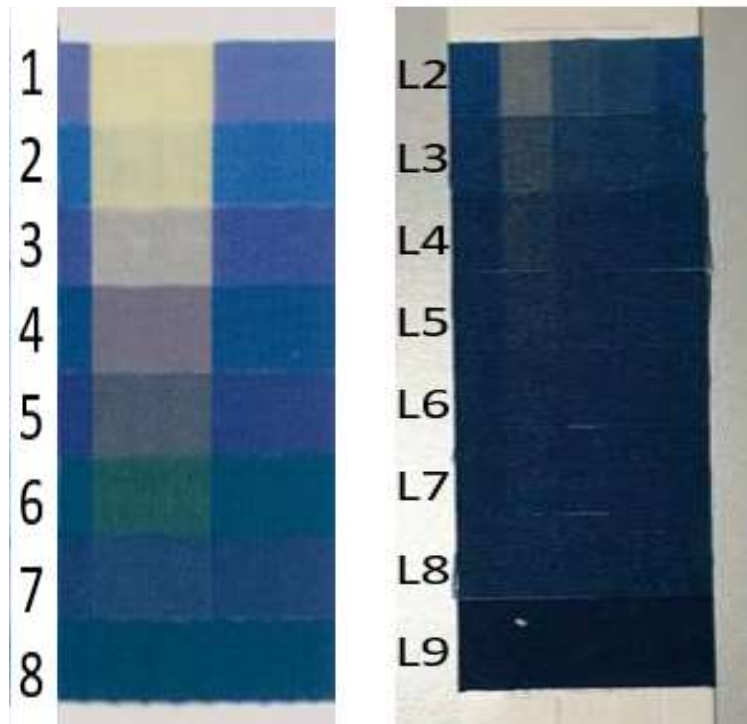


Figure 4: ISO (left) and AATCC (right), Blue Wool scales faded and unfaded

Note 3: Only the AATCC L2 blue wool is currently available (at release of this document).

Note 4: 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.

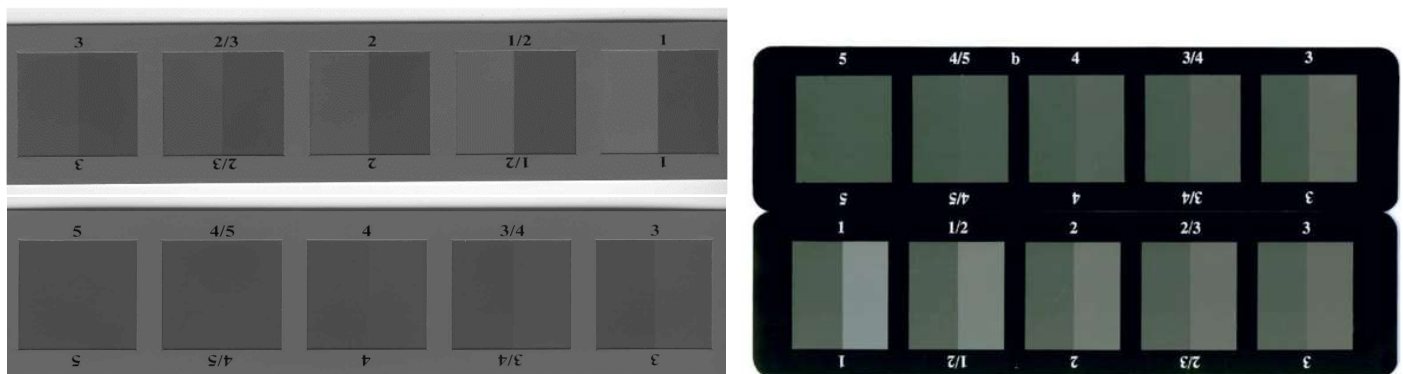


Figure 5: ISO (left) and AATCC (right) Grey Scale for visual evaluation of color change

Color Fastness Testing

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. 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. [16,17] Furthermore, ISO 105-B02 is also often used to evaluate leather, paper, and printing inks.

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 others who avoid the use of Blue Wool for their test duration and simply base it on a defined test time or radiant exposure.

The American test method AATCC TM16.3 has the same purpose as ISO 105-B02 but uses different test parameters and a different, more aggressive Window Glass filter. 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/m² nm at 420 nm or 864 kJ/m² total UV from 300 nm to 400 nm. AATCC TM16.3 has three test options, while mostly Option 3 is used in the industry.

3.2 Indoor Leisure and Sporting Goods made of Polymers

Indoor sporting goods partially or completely made of polymers are basically following testing like textile color fastness testing. However, a slightly higher irradiance level of 50 W/m² instead of 42 W/m² (at 300-400 nm) is applied. The complete method is described in ISO 4892-2 Method B. Since the major interest lies in checking sufficient color stability, test specimens are evaluated after xenon-arc exposure for their color change by visual inspection or with a colorimeter.

3.3 Indoor Leisure and Sporting Goods with Coatings

Indoor sporting goods with coatings follow the same testing as polymers, since the water effect in indoor environments is practically negligible. The complete method is described in ISO 16474-2 Method B. The test method is harmonized with ISO 4892-2 Method B (see 3.2). Since color stability is often the main interest, test specimens are evaluated after xenon-arc exposure for their color change by visual inspection or with a colorimeter.

4. Summary

Indeed, Leisure and Sporting Goods is a vast field of different products made of different materials. However, xenon-arc weathering technology is providing us amazing testing flexibility. Therefore, every Leisure and sporting Good application finds its suitable xenon test. Each supporting you on your way determining for your product the right amount of stabilization and durability against the effects of sunlight, heat, and water.

The methods described in this guide are general test methods for sporting and leisure equipment. Please note, some specific applications/products do have their own test standards. However, since those product specific test methods typically refer to one of the presented general methods, we did not expand this guide explicitly for those shown in **Table 5** in the **Annex**.

At Atlas, we prefer to focus on the shortest test duration, enabling the product development teams of the world to make optimal material choices quickly. All based on leading outdoor and laboratory technologies and over 100 years of expertise in transforming natural exposure scenarios into accelerated tests.

Contact us whenever you need support to achieve your product development goals efficiently.

5. Annex – Application-Specific Testing Standards

ISO 5912:2020 Camping tents — Requirements and test methods	ISO 105-B04
ISO 23537-2:2023 Requirements for sleeping bags — Part 2: Fabric and material properties	ISO 105-B02
ISO 20712-2:2007 Water safety signs and beach safety flags — Part 2: Specifications for beach safety flags — Colour, shape, meaning and performance	ISO 105-B02/B03
EN ISO 20471:2013 + A1:2016 High visibility clothing - Test methods and requirements	ISO 105-B02
ISO 12402-7:2020 Personal flotation devices - Part 7: Materials and components - Safety requirements and test methods	ISO 4892-1/2
ISO 15027-1:2012 Immersion suits — Part 1: Constant wear suits, requirements including safety	ISO 105-B04
EN 12277:2019 Mountaineering equipment - Harnesses - Safety requirements and test methods	
EN 958 Mountaineering equipment - Energy absorbing systems for use in klettersteig (via ferrata) climbing - Safety requirements and test methods	
EN 15567-1:2015+A1:2020 Sports and recreational facilities - Ropes courses - Part 1: Construction and safety requirements	

Table 5: Application-specific xenon testing and standard reference.

6. References

- [1] ISO 105-B10:2011 Textiles - Tests for colour fastness - Part B10: Artificial weathering - Exposure to filtered xenon-arc radiation.
- [2] Andreas Riedl, Florian Feil: Spectral irradiance distribution and reference spectra in weathering testing. Atlas Technical Guide 110. March 7, 2023. <https://lp.atlas-mts.com/guide-about-irradiance-spectra-in-weathering-testing>
- [3] Publication CIE 241:2000 Recommended Reference Solar Spectra for Industrial Applications
- [4] ISO 105-B04:2024 Textiles - Tests for colour fastness - Part B04: Colour fastness to artificial weathering: Xenon arc fading lamp test.
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- [9] ISO 16474-2, Paints and varnishes - Methods of exposure to laboratory light sources - Part 2: Xenon-arc lamps, (ISO 16474-2:2013 + Amd.1:2022).
- [10] ASTM D7869, Standard Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings, 2017.
- [11] ISO 105-B02:2014, Textiles - Tests for colour fastness - Part B02: Colour fastness to artificial light: Xenon arc fading lamp test.
- [12] AATCC TM16.3, Test Method for Colorfastness to Light: Xenon-Arc, 2014.
- [13] Marks & Spencer, Colour fastness to light.
- [14] ISO 105-A02, Textiles; tests for colour fastness; part A02: grey scale for assessing change in colour, 1993.
- [15] AATCC Evaluation Procedure 1, 2020.
- [16] IS 2454, Methods for determination of colour fastness of textile materials to artificial light (xenon lamp), 1985.
- [17] GB/T 8427, Textiles -- Tests for color fastness -- Color fastness to artificial light: Xenon arc, 2019.

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