Atlas Standards Guide 100

Automotive Weathering Tests

Summary of Interior and Exterior Weathering and Lightfastness Test Methods for Automotive Applications

Atlas Material Testing Technology

November 23, 2021

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Introduction

The demands made on the properties, appearance, and durability of materials and components in the automotive industry have increased significantly in recent decades. Simultaneously, increasing competition has forced the industry to progressively reduce costs. To meet these challenging requirements, testing technology has undergone continuous development. This is especially applicable for laboratory accelerated exposures where better simulation and ultimately correlation are critical. While outdoor weathering and lightfastness plays a key role in any durability testing program, the long test durations and costs force automotive original equipment manufacturers (OEMs) and their suppliers to make product decisions on the accelerated testing results.

Today, the automotive industry employs numerous advanced methods in both laboratory and outdoor tests. The purpose of this article is to organize and structure the variety of the existing test methods and highlight differences and similarities. As most automotive companies are basing their company specifications on a few international and national standards, the article focuses on these basic weathering test methods. More detailed discussion of certain test aspects is restricted to xenon-arc technology only because this is the most advanced and most widely used light source for accelerated testing of automotive materials. Finally, selected current and future trends in testing technology are presented.

Whether a method is suitable for specific applications - whether laboratory results correlate with those from outdoor exposure or the damages that occur during actual use—depends on several factors such as the material itself, the property selected for evaluation, and last but not least, on the actual conditions during outdoor or real-world exposure. In the end, only testing data can help to decide if a specific test method is suitable or not. As this article does not include data, the methods presented will not be rated against each other.

Overview

Weathering tests can be performed during every step in the development and production process. Supplied materials can be subjected to a quality inspection. The development of new materials—e.g., plastics for vehicle interiors or modified paint systems—also require significant testing. Finally, components, complete prototypes as well as full vehicles can undergo weathering testing to obtain insights into the interaction of all components under the influence of solar radiation, heat, and water.

Various test equipment is used for laboratory weathering for automotive interior and exterior applications. Test instruments can be classified by:

- type of the light source, e.g., xenon-arc, metal halide, fluorescent, or carbon-arc
- instrument geometry, e.g., with a sample rack rotating around the light source (Figure 1), or using a static plane sample area (Figure 2), and
- instrument size and sample capacity, e.g., bench top, free standing devices, walk-in and even drive-in chambers [1].

***Figure 1**. Atlas Ci4400 Weather-Ometer® xenon-arc instrument with a rotating rack configuration*

***Figure 2**. Atlas SUNTEST XXL+ xenon-arc instrument with a flat-bed configuration*

For outdoor testing, sample racks with differing inclinations, different backings (with or without plywood or “Black-Box” backing), with and without glass cover panels, are employed. Fresnel mirrors are used to concentrate the sunlight on the samples a method which requires efficient sample cooling. With the aid of sensors and mechanical drives, open sample racks, behind glass exposure cabinets, and Fresnel solar concentrator devices (Figure 3) can track the sun’s path to maximize radiant exposure during a test. In some setups, such as the glass covered IP/DP-Boxes (**I**nstrument **P**anel / **D**oor **P**anel), the temperature is controlled within specific limits using built-in fans and heaters. Fresnel devices can also be equipped with spray systems, which operate at fixed intervals during daytime exposure or at night (NTW, or Nighttime Wetting).

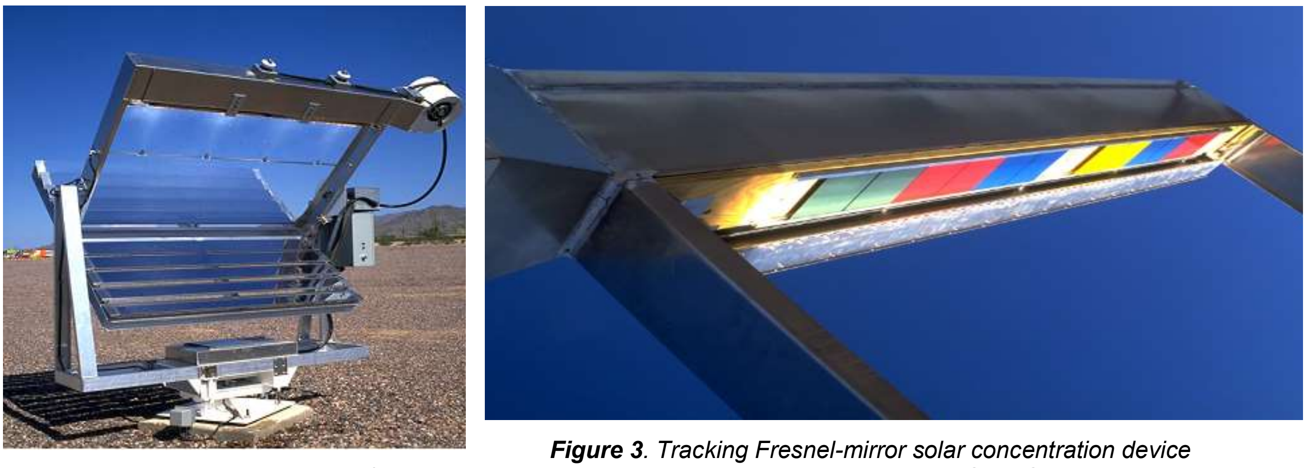

***Figure 3**. Tracking Fresnel-mirror solar concentration device (10 mirrors, with spray nozzles, left); target board with test specimen (right) according to ASTM G90*

Figure 4. Sun-tracking carousel to measure automotive interior surface temperatures. By tracking the sun and orienting the vehicle at different angles with respect to the sun, maximum surface temperatures can be measured on all surfaces

Where entire vehicles are exposed, turntables can be used to track the sun (Figure 4). Overnight exposure using artificial light has not prevailed as a viable testing method, but some automobile manufacturers take advantage of two summers in one year by semi-annually moving vehicles from the Northern to the Southern Hemisphere and back. Naturally, the specific climatic conditions observed at the selected exposure site play a crucial role in the weathering results. For example, Arizona and the Kalahari have a hot, dry climate ("arid"), South Florida is warm and humid ("subtropical"), and Jacksonville in northern Florida is known for heavy industrial air pollution. Figure 5 shows an Atlas outdoor exposure facility in South Florida. The article by Hardcastle and Searle in "Plastics and Coatings" [2] provides an in-depth description of the various outdoor weathering test methods.

Table 1, a selection of the most important laboratory and outdoor weathering methods are arranged by their application to materials, components, and entire vehicles, differentiated according to their application for vehicle interiors and exteriors.

Application		In the Laboratory	Outdoors
Materials	Interior	• Hot light with xenon • Xenon with normal E • Xenon with high E	• Under glass, static or with sun tracking • Fresnel solar concentrator (under glass) • Open or closed box, possibly heated • Black box under glass
	Exterior	• Xenon with normal E • Xenon with high E • Fluorescent/UV test	• Open sample rack, with or without backing • Fresnel solar concentrator, with or without water spray • Black box
Components	Interior	• Metal halide solar simulation device • Large xenon device	• Under glass, static or with sun tracking • Open or closed box, possibly heated • IP/DP Box®, with or without sun tracking • Black box under glass
	Exterior	• Metal halide solar simulation device • Large xenon device	• Open sample rack, with or without backing • Black box
Vehicles		• Solar simulation and climate chamber	• Florida, Arizona, Jacksonville, etc. • Static or dynamic (e.g., turntable) • 2 summers per year

***Table 1**: A Selection of the most important laboratory and outdoor weathering methods for automotive applications*

***Figure 5**. Outdoor exposures in a sub-tropical climate of South Florida, representing one of the 'benchmark' climates for automotive exterior weathering testing.*

Table 2 employs the same structure as Table 1, except that it lists the most important standards used in the automotive industry rather than the employed test methods. Individual company specifications are not included in this general table.

Application		In the Laboratory	Outdoors
Materials	Interior	• ISO 105-B06 • ISO 4892-2 • VDA 75202 • SAE J2412 (SAE J1885) • JASO M346	• ISO 877-1/2/3 • ISO 2810 • SAE J2229 • SAE J2230 • ASTM G24
	Exterior	• ISO 4892-2 • ISO 16474-2 • ISO 11507 • ISO 4892-3 • VDA 621-430 • SAE J2527 (SAE J1960) • SAE J2020 • JASO M351 • ISO 3917	• ISO 877-1/2/3 • ISO 2810 • SAE J951 • SAE J1961 • SAE J1976 • ASTM G7 • ASTM G90
Components	Interior	• DIN 75220 • ISO 4892-2	• SAE J2229 • SAE J2230 • ISO 877-1/2/3 • ASTM G24
	Exterior	• DIN 75220 • ISO 4892-2	• ASTM G7
Vehicles		• DIN 75220 • Company specifications	• SAE J951 • Company specifications

***Table 2:** Common testing standards categorized in the same manner as Table 1*

Basic Xenon-arc Standards for Plastics and Coatings

There are two series of standards in ISO, one for plastics and one for coatings, that serve as the basic methods from which many other test methods are derived. Both standards are widely applied globally in the automotive industry and therefore presented in detail. ASTM G151 (General Requirements) and G155 (Xenon-Arc exposures) are similarly organized as the ISO series of standards.

ISO 4892-2, Plastics - Methods of Exposure to Laboratory Light Sources - Part 2: Xenon-arc Sources [3], **ISO 16474-2 Paints and Varnishes - Artificial Weathering and Exposure to Artificial Radiation - Exposure to Filtered Xenon-Arc Radiation** [4] and **ASTM G155, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials** [5] all compile test options in a table of several “cycles,” all depending on the end-use of the material tested and the configuration of the instrument being used for the test. In the latest revisions, care was taken during this revision to ensure that the test parameters in the ISO standards are as similar as possible and the two documents do not contradict to each other.

Note: these international standards are generally adopted by national standardization organizations. In China, the SAC is the responsible standardization body. Chinese standards are published as GB standards (Guobiao standards).

All of these standards were last revised in 2013. ASTM G155 is currently going through a major revision and is expected to be published later this year. The recommended cycles in these standards typically require control of the main weathering test parameters:

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

Also, inclusion of periodic sprays, light/dark cycling, and the timing of phases within each cycle are also detailed in these standards. Most xenon-arc test methods used for automotive interior and exterior applications are based on and refer to at least one off these basic test specifications.

Laboratory Testing of Automobile Interior Materials

“Hot lightfastness testing” is an exposure method combining relatively high temperatures with the radiation from a filtered xenon-arc lamp. What is meant by “high” temperatures for these automotive interior tests? “Normal” Black Standard Temperatures (BST) are specified, for example, in ISO 105-B02 [6] a maximum of 47 °C (or 45 °C for Black Panel Temperature, respectively) is used for typical interior applications, and 65 °C for typical outdoor applications in ISO 4892-2 and ISO 16474-2. However, on a hot summer day, significantly higher surface temperatures, often above 100 °C, have been measured on automotive interior surfaces. Therefore, special hot lightfastness test methods are typically used for automotive interior materials to better simulate these extreme conditions. Most interior test specifications use so-called “window glass filtered” xenon-arc radiation to simulate solar radiation in an automotive cabin, behind glass.

The most common test methods for automotive interiors are ISO 105-B06 [7] (similar to German automotive specification VDA 75202), ISO 4892-2 Cycle 3 for Plastics, ISO 16474-2 Cycle 3 for Coatings, the Japanese automotive standard JASO M346, and SAE J2412 [8] (former SAE J 1885) from the American Society of Automotive Engineers. ISO 105-B06 includes several different test conditions, partially identical to these other specifications. Table 3 below provides a summary of the parameters of these general hot lightfastness test methods.

Standard	BST, °C	BPT, °C	CHT, °C	Dark Phase	Filter System	Irradiance, W/m^2 (300 - 400nm)	RH, %	Country
ISO 105-B06 Set of cond. no 2	90	--	45	No	Window Glass	Not Specified	45	France
ISO 105-B06 Set of cond. no 6	--	89	50	No	Window Glass	162	50	Japan
ISO 105-B06 Set of cond. no 3	100	--	65	No	Window Glass	45-162	30	Global
SAE J2412*	--	89	62	Yes	Extended UV	0.55 (340 nm)	50	USA
JASO M346	--	89	not spec	No	Window Glass	48 - 162	50	Japan
VDA 75202 Option A	100	--	65	No	Window Glass	44 - 150	20	Germany
ISO 4892-2 Method B Cycle 3	100	--	65	No	Window Glass	50	20	Global
ISO 105-B06 Set of cond. no 1	115	--	48	No	Window Glass	70 - 90	20	Germany
GMW 14162, Method B	100	--	65	No	Window Glass	60	20	USA
FLTM BO 116-01	--	89	62	Yes	Extended UV + SF-5	1.10 (420 nm)	50	USA

*formerly SAE J1885; same parameters as ISO 105-B06 Conditions 5

Table 3: *Test parameters of general hot lightfastness tests*

One subject where methodology differs relates to the application of a dark phase. SAE J2412 and FLTM BO 116-01 require a light/dark cycle. In contrast, most other test methods use a continuous exposure to radiation.

The type of sample backing frequently causes errors in hot lightfastness testing as it greatly influences the test results. The existing standards and company specifications do not treat this topic uniformly, if they deal with it at all, so that, when comparing results. If not clearly defined in the test method, the type of sample backing (metal, cardboard, non-woven fabric) should always be agreed upon and reported.

Most European, American, Japanese, Korean and Chinese OEM specifications refer to one of those test methods mentioned above. However, they commonly have additional requirements regarding the optical filters, sample mounting and handling, instrument types and other test details. Typically, they also define the acceptable property changes after a minimum exposure. These details cannot be published in this general overview but are available from the OEMs.

For reference, Table 4 below lists selected company specifications for testing of automotive interiors, which are derived from the basic standards in Table 3.

Company	Ford	GM	GM	Volkswagen
Method	FLTM BO 116-01	GMW 14162, Method B	GMW 3414TM	PV 1303
Based on:	Modified SAE J2412	ISO 105-B06	Modified SAE J2412	ISO 105-B06
Cycle	3.8 h light / 1 h dark	Light only	3.8 h light / 1 h dark	Light only
Filter system	Ext. UV + SF-5 glass	Window Glass	Quartz/CIRA on SL + Float	Window Glass
UV cut-on	335 nm	315 nm	320 nm	315 nm
E, 300-400 nm, W/m^2		60	95	60
E, 420 nm, $W/(m^2nm)$	1.1		2.2	1.2
BPT / BST in °C, in light phase	89 (BPT)	100 (BST)	115 (BST)	100 (BST)
BPT in °C, dark	38		38	
CHT in °C, light	62	65	65	65
CHT in °C, dark	38		38	
RH in %, light	50	20	25	20
RH in %, dark	95		95	

Table 4: *Selected company specifications for testing of automotive interiors*

Laboratory Xenon Testing of Automotive Exterior Materials

Table 5 illustrates the most common general methods for testing automotive exterior materials.

For many years, the German automotive industry has employed VDA coatings guidelines no. 621-429 on "Colour Stability" and no. 621-430 on "Cracking Resistance", even though these two drafts have never been officially published by VDA. Both guidelines represent an "adaptation" of SAE J1960 to the German testing environment during the 1990s. However, it must be remembered that both guidelines are based on the results of extensive ring studies that confirmed the correlation to Florida exposure for the paint systems in use at the time.

Today ISO 16474-2 Cycle 1 (harmonized with ISO 4892-2 Cycle 1) and SAE J2527 (performance based and updated version of SAE J1960) are the most common test methods automotive OEMs refer to in their test specifications for exterior coatings and materials. ISO 16474-2 Cycle 1 is a two-hour test cycle consisting of a 102-minute dry phase followed by an 18-minute spray phase, with continuous light. SAE J2527 [9] uses a more complex 3-hour cycle consisting of light/dark and dry/spray phases as described in Table 6.

As with interior materials, these adoptions often include refinement or adjusting of test parameters, such as the spray/dry cycle. Those details cannot be published in this general overview but are available from the OEMs.

It should be noted that the two SAE standards - both J2527 and J2412 - require that any test equipment be validated for this application using the "acceptance protocol" according to SAE J2413.

Standard	BST °C	BPT °C	CHT, °C	Dark Phase	Filter System	Irradiance W/m² (300 – 400 nm)	RH, %	Country
VDA 621-429, Option 8.1		55	36-41	No	Daylight	45	>60	Germany
VDA 621-429, Option 8.2		55	36	No	Daylight	80	>60	Germany
VDA 621-429, Option 8.3		55	38	No	Daylight	55	55	Germany
ISO 16474-2 Cycle 1 (and ISO 4982-2 Cycle 1)	65		38	No	Daylight	60**	50	Global
JASO M351, Normal		63	not spec.	Optional	Daylight	60-180	50	Japan
JASO M351, High T		83	not spec.	Optional	Daylight	60-180	50	Japan
SAE J2527*	Four-phase cycle noted in Table 6 below							
ASTM D7869	Complex cycle noted in Table 7 below							USA

*) replaces SAE J1960. **) the corresponding narrowband irradiance at 340 nm is 0.51 W/(m² x nm).

***Table 5:** Most common general methods for testing automotive exterior materials*

Current Trends

One characteristic feature of weathering tests according to the United States automotive standards SAE J2527 is that it consists of four phases, including simultaneous water spray on the front and back of the samples for one hour during a dark phase (Table 6). However, it was determined that this relatively lengthy dark phase did not simulate the amount of water uptake for many coating systems that was found to be achieved during long periods of dew (condensation) formation during the night hours of South Florida exposures. Additionally, the filter combination specified (either Extended UV or traditional Daylight) did not always produce the same chemical changes as found in natural weathering exposures.

Parameter	Irradiance, W/m² at 340 nm	BPT, °C	CHT, °C	RH, %	Phase Type	Phase Length (min)
Phase 1	Dark	38	38	95	Dark w/ Front and Back Spray	60
Phase 2	0.55	70	47	50	Light Only	40
Phase 3	0.55	70*	47	50*	Light w/ Front Spray	20
Phase 4	0.55	70	47	50	Light Only	60

*While these are the control set points in the spray phase, it is understood that the influence of the spray water does not allow for the BPT and %RH to be controlled during this phase.

***Table 6:** Detailed SAE J2527 test cycle*

After over 10 years of developmental work, a consortium of automotive OEMs, automotive paint suppliers, and weathering instrument manufacturers, developed a new test method that has been published as ASTM D7869. This test method is a complex, multi-phase, 24-hour cycle, that better replicates South Florida exposures (Table 7). Additionally, the test method has very tight requirements for the spectral irradiance, resulting in a cut-on wavelength that matches that of peak natural daylight nearly identically, as noted in Figure 6.

Parameter	Irradiance, 340 nm in W/(m²nm)	BPT, °C	CHT, °C	RH, %	Phase Type	Phase Length (min)
Phase 1	Dark	--	40	95	Dark w/ Spray	240
Phase 2	0.40	50	42	50	Light	30
Phase 3	0.80	70	50	50	Light	270
Phase 4	0.40	50	42	50	Light	30
Phase 5	Dark	--	40	95	Dark w/ Spray	150
Phase 6	Dark	--	40	95	Dark w/ Spray	30
Phase 7	0.40	50	42	50	Light	20
Phase 8	0.80	70	50	50	Light	120
Phase 9	Dark	--	40	50	Dark	10
Phase 10	Repeat steps 6 through 9 an additional three times. Total cycle time is 24 hours					

Table 7: *Detailed ASTM D7869 test cycle*

The long 4-hour dark-with-spray phase allows coatings to uptake a similar amount of water as in natural exposures. The “transition” phases (2, 4, and 7) allow for panels to gradually dry and heat up as normally occurs in the real world as well. The longer, high irradiance phases (3 and 8) provide higher acceleration than typical xenon-arc tests. The sub-cycle of phases 6 to 9 simulate daily cycling and rain periods where the coating does not achieve total saturation as is phase 1. An annex in ASTM D7869 describes the purpose and justification for each phase in detail. The test development work and data associated with it can be found in Reference [10].

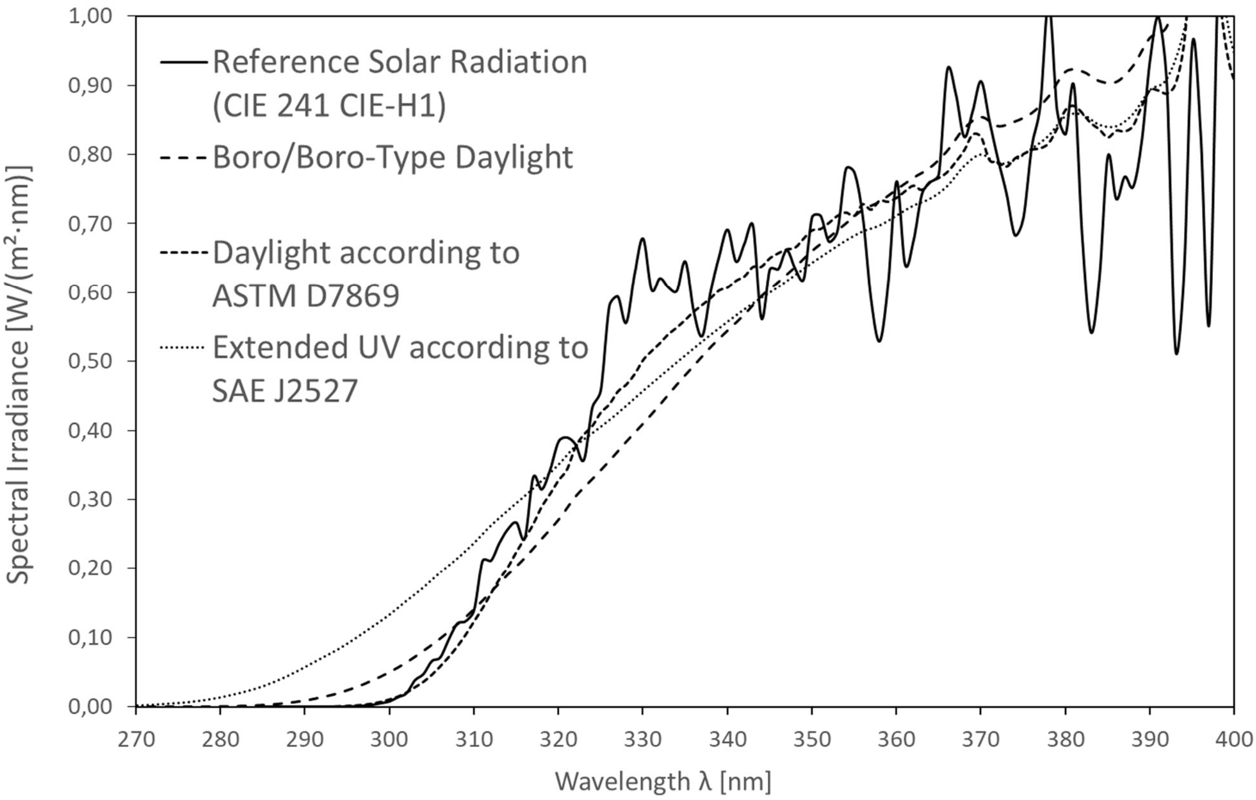

Figure 6. Comparison of spectral irradiance distribution in the UV range for traditional Daylight, Extended UV as required in SAE J2527, and new requirements in ASTM D7869, all compared to a reference solar radiation spectrum.

Testing with High Irradiance Levels

The most important basic international standards (ISO 4892-2, ISO 16474-2, ISO 105-B06), as well as many national standards (JASO M346, JASO M351, VDA 75202), permit the employment of irradiance levels up to three times the maximum solar radiation at ground level, which is usually specified as 3 x 60 = 180 W/m^2 in the UV. While this development is mainly based on Japanese initiatives, the concept is also being examined in several other countries. In Germany, high irradiation levels in conjunction with high temperatures have been successfully used for lightfastness tests of various technical polymers and textiles intended for automobile interiors [11, 12]. This accelerated test method must be very carefully applied in each instance and must be adjusted to the specific material and properties being examined. High irradiation levels may possibly induce photochemical effects that do not occur under normal conditions. If the results obtained from tests at high irradiance are compared with those obtained at normal levels, all other test parameters—i.e., spectral irradiance distribution, BST/BPT, CHT, and RH—must be identical.

Optimizing the UV Cut-on

Primarily in SAE test methods, high acceleration in weathering tests is achieved by employing short wavelength xenon-arc radiation that does not occur in natural solar radiation outdoors. The “original” SAE standards on materials for automobile exteriors and interiors, SAE J1885 and J1960, specify a quartz/borosilicate filter system, which contains an unrealistically high UV portion of radiation below the generally established cut-on wavelength of 295 nm. This filter system, whose cut-on wavelength lies at approximately 275 nm, is indicated by “Extended UV” in the above tables.

SAE J1885 and J1960 have been withdrawn and replaced by updated performance-based standards. While SAE J2527 for automotive exteriors alternatively permits more realistic Daylight filters (often referenced as Boro-S/Boro-S), the corresponding method for automotive interiors, SAE J2412, makes no such concession. In contrast, major automotive manufacturers have, during the past several years, developed their own company for automotive interior materials specifications based on SAE J2412, but using a more realistic UV cut-on wavelength than previously specified, such as 335 nm, more representative of real automotive glass types. [13]

The Daylight filters used for SAE J2527 still allow a little more of short-wavelength UV radiation compared to natural solar radiation. For exterior materials, the ASTM D7869 spectral requirements have been tightened even more to require a precise cut-on to peak natural sunlight at 295 nm.

Summary

Most lightfastness and weathering test methods for automotive interior and exterior applications are based on a few established general test standards. Latest trends show that there is an increased demand in accelerated test methods, that reproduce more reliably the climatic parameters and thus are likely to cause more realistic degradation processes. This finally led to the development of better test technology and new test methods. We expect future developments in standardization to continue in the direction of more realistic testing and that more automotive OEMs will adopt these developments in their test specifications.

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This paper is adapted from the following original publication:

Riedl, Andreas: "Weathering and Lightfastness Testing in the Automotive Industry – Overview and Current Trends" In SUNSPOTS Volume 35, Issue 74, Summer 2005. Pages 1 ff.

The content has been updated to represent the current status.

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