Atlas Standards Guide 104

Metal Halide Solar Simulators

Summary of

Solar Environmental Stress Testing

Atlas Material Testing Technology

May 5, 2022

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Introduction

Solar environmental product testing can be regarded as an adjacent and often complementary part to accelerated xenon weathering. While xenon technology is perfectly suited for qualifying new materials for new products, metal halide solar simulators show their strength in high efficiency combined with realistic solar heat loading.

Filtered Xenon Technology

Filtered xenon based solar simulation provides us an excellent match to natural solar UV needed for weathering testing. A perfect UV Cut-on wavelength and complete UV band without gaps between 290-380 nm. Furthermore, stable spectral irradiance over a wide control range for applying different irradiance levels, suiting the individual application. We have optical filters to adjust for realistic outdoor/indoor spectra. Together with tight temperature controls, xenon technology is perfect for qualifying new materials for new products. Determining the appropriate light stabilizer types/amounts to protect against the effects of sunlight and UV in specific. The disadvantage of being less efficient than metal halide is rather small, because material testing does not require large test chambers. Note, existing large xenon test devices can test more than 100 specimens simultaneously.

	Xenon Weathering/Lightfastness Testing	Solar Environmental Stress Testing
Scope	Material testing	Component & Product testing
Basis	Material aging majorly driven by time-compressed photo-induced chemical degradation under controlled surface temperature	Product/Component aging by solar heat load and climatic cycling (physical) stress
Benefit	Time-saving R&D tool for material service life prediction / material property change evaluation (cracking, loss of strength, gloss loss, yellowing, color fading, chalking, haptics, etc...)	Time-saving R&D tool for testing interaction of different materials/components under climatic extremes. Their aging effect on product performance and functionality (A/C, airbags, navigation, electronics; noise, clearance, tension cracks, emissions, etc...)
Methodology	Long (typically >1000 h) steady state tests under natural/intensified maxima E, T, RH, plus wet/dry cycles Focus on realistic UV and narrow test temperature tolerances, dark phases short or ignored Specimens: standardized small, flat Supportung natural exposures / correlation studies vs laboratory test	Short* (240 h) cycling climatic stress (hot & dry - cold & humid) combined with realistic solar heat build-up Short* (25 d) steady state solar climatic tests Focus on realistic visible and IR radiation more important than UV Specimens: random large, 3-dimensional Supportung natural exposures / correlation studies vs laboratory test

***Table 1:** Xenon weathering and lightfastness testing vs. solar environmental stress testing.*

Filtered Metal Halide Global Technology (MHG)

Once the material decision is made, components and final products are manufactured. Since materials are already weathering tested with xenon, component and final product testing focuses on product performance and functionality testing under realistic solar stress, especially solar heat load. MHG technology, due to its high efficiency and realistic heat load testing capabilities is ideal for any large-size (larger than xenon) test chambers. We will see, the also called solar environmental stress tests though dealing also with product aging are quite different compared to xenon weathering testing. The major differences are summarized in Table 1.

Small MHG Based Solar Environmental Chambers (SEC)

Small of SEC come with custom designed single MHG solar simulator such as SolarConstant MHG 2500/4000 (Figure 1).

- Type of light source: filtered MHG luminaires (2500 W / 4000 W) on top of test chamber
- Design: horizontal specimen tray; ~50 cm space below a reference level to fit large 3-D specimens
- Chamber volume: 600 - 1200 liters
- Irradiance range: 500 - 1200 W/m² (at 280 - 2500 nm)
- Temperature range: -20 °C to +100 °C with irradiation
- Humidity range: 10 to 80 % with irradiation
- Airflow: partly controlled

Figure 1: *SEC chamber with SolarConstant MHG 4000; size ca. 1000 l.*

Large MHG Based Solar Environmental Chambers (SEC)

Large SEC are typically walk-in designs with custom designed multi-MHG solar simulators such as SolarConstant MHG 4000 (Figure 2).

- Type of light source: filtered MHG luminaires (4000 W) on top of test chamber
- Chamber volume: aligned to fit two automotive indoor test-boxes
- Irradiance range: 800 - 1100 W/m² (at 280 - 3000 nm)
- Temperature range: -20 °C to +100 °C with irradiation
- Humidity range: 10 to 80 % with irradiation
- Airflow: controlled

Figure 2: *SEC Walk-in chamber with four units of SolarConstant MHG 4000.*

MHG Based Drive-in Solar / Solar Environmental Chambers

MHG based Drive-in chambers are heavily used by the automotive/transportation industry. Drive-in chambers come with custom designed metal halide solar simulators such as SolarConstant MHG 4000. The number and fixation design (frames) tailored towards each individual client needs, e.g., including automatic movement and positioning of frames.

- Type of light source: filtered MHG luminaires (4000 W) under the roof
- Chamber volume: aligned to fit one vehicle
- Irradiance range: 800 - 1100 W/m² (at 280-3000 nm)
- Temperature range: depending
- Humidity range: depending
- Airflow: depending

Figure 3: *Drive-in chamber with 19x SolarConstant MHG 4000; inclined side frames.*

General Standard Global Solar Radiation

Publication CIE No. 241 by the International Commission on Illumination (CIE = Commission Internationale de l'Éclairage) contains a benchmark spectrum for simulating worst-case solar irradiance in weathering instruments [1]. In 2020, it replaced the previous version CIE No. 85 Table 4.

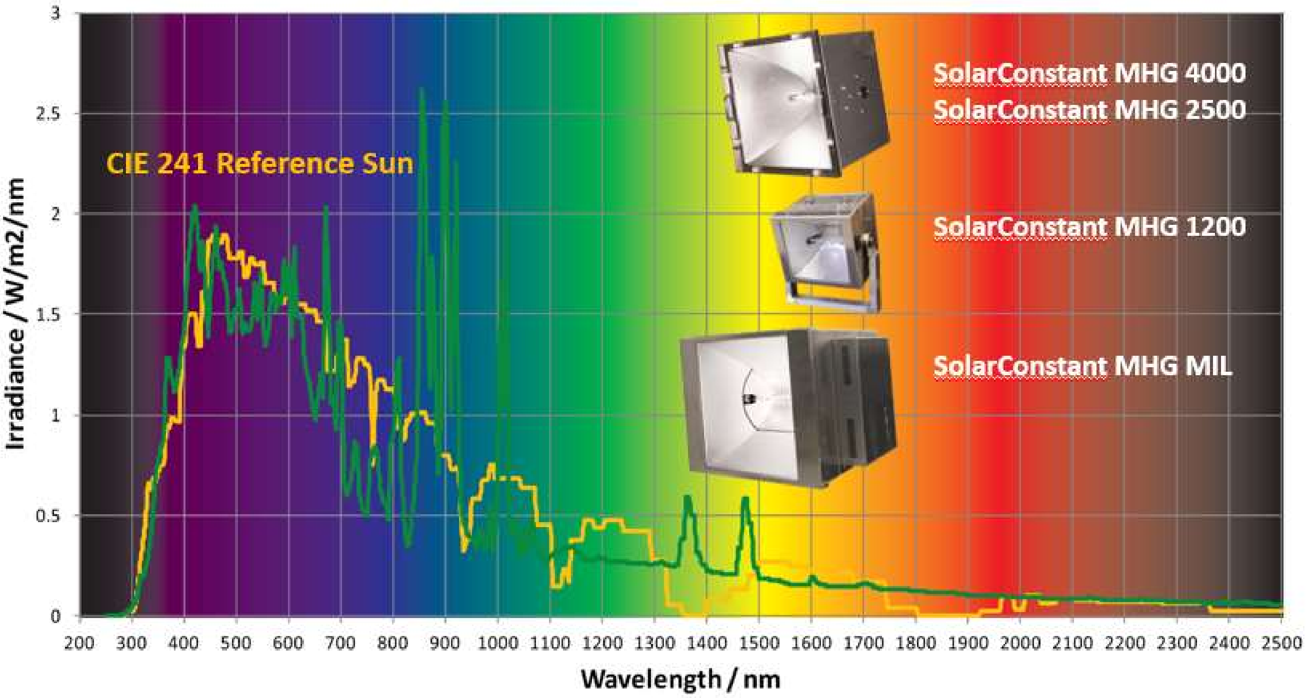

Figure 4: *Atlas SolarConstant MHG series exemplary Daylight spectrum (green) compared to CIE 241 reference sun*

Overview Of Test Methods Using MHG Solar Simulators

There are four to five major industries that are heavily using MHG based solar simulators for their testing:

- Automotive / Train
- Defense
- PV Solar, and
- Electronics.

The most common standards by industry are listed in Table 2, the most frequently used as first in each column. Those four standards – DIN 75220 [2], MIL-STD-810H [3], IEC 61215-1/-2 [4,5], and IEC 60068-2-5 Sa 1-3 [6] can be further regarded as basic standards. Those already exist for decades and are either referenced or laid the basis for younger standards.

Automotive / Train	Defense	PV Solar / Collectors	Electronics
DIN 75220	MIL-STD-810H (505.7)	IEC 61215-1/-2	IEC 60068-2-5 (Sa 1-3)
VDA 230-219	DEF STAN 0035	IEC 60904-9 ED3	GB/T 2423.24
ISO 12097-2	STANAG 2895	IEC 61730-2	
GB/T 19233-2020	STANAG 4370 (M. 305)	EN12975-3	
GB/T 40711.3-2021	GJB 150.7A		
GB/T 18286.1-rev.			
TCSAE 70-2018			
EPA 40 CFR / SC03			
BMW PrV 306.5			
MBN 55555-5			
VW PV 1211			
Renault 32-00-022			
EN 13129			
EN 14750-2			
J2777_201601			

Table 2: *Most common solar environmental testing standards by industry.*

Automotive/Train

The DIN 75220 standard covers in total twelve test methods: 2 cyclic outdoor climatic tests, 4 cyclic indoor climatic tests, and 6 steady-state tests for outdoor and indoor climates. The cyclic tests are all based on practical 24 hour schemes - typically 10-15 times repeated (240 to 360 h). The long-term tests are run for 240 h). All those solar environmental stress testing focus on how the components perform and age under realistic environmental stress – from desert like conditions to the arctic frost. Not another UV-durability test. Table 3 shows the six steady state tests, and Table 4 the six cyclic tests specified in DIN 75220.

	Shortform	Duration (h)	Standard Table	Chamber Temperature	Relative Humidity	Irradiance
Long-Term Tests	D-OUT-T	240.0	2	42°C +/- 3°C	< 30%	1.000 +/- 100 W/m²
	D-OUT-F	240.0	2	42°C +/- 3°C	> 60%	1.000 +/- 100 W/m²
	D-IN1-T	240.0	3	80°C +/- 3°C	< 30%	830 +/- 80 W/m²
	D-IN1-F	240.0	3	80°C +/- 3°C	> 40%	830 +/- 80 W/m²
	D-IN2-T	240.0	4	65°C +/- 3°C	< 30%	830 +/- 80 W/m²
	D-IN2-F	240.0	4	65°C +/- 3°C	> 50%	830 +/- 80 W/m²

Table 3: *Steady state tests in DIN 75 220.*

		Shortform	Duration (h)	Standard Table	Chamber Temperature	Relative Humidity	Irradiance
1. Cycle	Outdoor / Dry climate	Z-OUT-T	8.0	2	42°C +/- 3°C	< 30%	1.000 +/- 100 W/m²
			3.5	5	10°C +/- 3°C	> 55%	
	15 cycles / 360 hours		8.0	2	42°C +/- 3°C	< 30%	1.000 +/- 100 W/m²
			3.5	5	10°C +/- 3°C	> 55%	
			1.0	Service	Room conditions (ca. 23°C / 50% rH)		
2. Cycle	Outdoor / Humid climate	Z-OUT-F	5.0	5	-10 +/- 3°C	Condensation permissible	
			12.0	2	42°C +/- 3°C	> 60%	1.000 +/- 100 W/m²
	10 cycles / 240 hours		6.0	8	-10°C +/- 3°C	Condensation permissible	
			1.0	Service	Room conditions (ca. 23°C / 50% rH)		
3. Cycle	Indoor1 / Dry climate	Z-IN1-T	8.0	3	80°C +/- 3°C	< 30%	830 +/- 80 W/m²
			3.5	5	10°C +/- 3°C	> 55%	
	15 cycles / 360 hours		8.0	3	80°C +/- 3°C	< 30%	830 +/- 80 W/m²
			3.5	5	10°C +/- 3°C	> 55%	
			1.0	Service	Room conditions (ca. 23°C / 50% rH)		
4. Cycle	Indoor1 / Humid climate	Z-IN1-F	5.0	5	-10°C +/- 3°C	Condensation permissible	
			12.0	3	80°C +/- 3°C	> 40%	830 +/- 80 W/m²
	10 cycles / 240 hours		6.0	5	-10°C +/- 3°C	Condensation permissible	
			1.0	Service	Room conditions (ca. 23°C / 50% rH)		
5. Cycle	Indoor2 / Dry climate	Z-IN2-T	8.0	4	65°C +/- 3°C	< 30%	830 +/- 80 W/m²
			3.5	5	10°C +/- 3°C	> 55%	
	15 cycles / 360 hours		8.0	4	65°C +/- 3°C	< 30%	830 +/- 80 W/m²
			3.5	5	10°C +/- 3°C	> 55%	
			1.0	Service	Room conditions (ca. 23°C / 50% rH)		
6. Cycle	Indoor2 / Humid climate	Z-IN2-F	5.0	5	-10°C +/- 3°C	Condensation permissible	
			12.0	4	65°C +/- 3°C	> 40%	830 +/- 80 W/m²
	10 cycles / 240 hours		6.0	5	-10°C +/- 3°C	Condensation permissible	
			1.0	Service	Room conditions (ca. 23°C / 50% rH)		

Table 4: *Cyclic tests in DIN 75 220.*

There are several OEM standards, which are derived from DIN 75220, e.g., BMW PR 306.5 Solar Simulation for automotive parts, and Renault 32-00-022 Solar Simulation test on complete Vehicles. Furthermore, there is VDA 230-219 Ageing automobile components in solar simulation units, which is for major parts identical to DIN 75220.

Defense

The United States Military Standard emphasizes solar radiation tests among many other stress tests. MIL-STD-810H includes two test procedures. Procedure I and Procedure II. The solar radiation test of MIL-STD-810 is a performance standard, which means you can use any solar simulation technique, which meets the requirements. Today, most users prefer MHG technology.

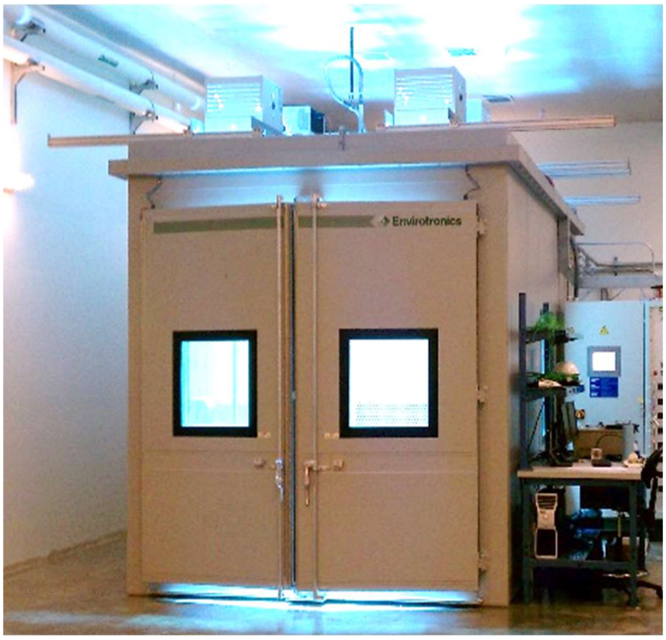

Figure 5: *Customized Walk-in MHG solar test chamber using 4x SolarConstant MHG MIL luminaires.*

As DIN 75220, also the two MIL standard procedures are setup for practical 24h cycles. Procedure I is all about the question: What are the max temperatures on surfaces and critical parts achieved during a hot sunny day - parts such as electronics, avionics, or other functional parts. Procedure I simulates realistic solar days, which are performed for 3-7 times. Procedure II simulates long solar exposures in hot desert like climates and is performed for 56 days providing 1120 h of solar exposure and 224 h of dark time.

PV Solar

Solar simulators can be either used for performance measurements of PV devices or endurance irradiation tests. Part 9 of IEC 60904 [7] provides the definitions of and means for determining simulator classifications for flashers (often xenon/LED) and steady-state solar simulators (often MHG), where A+ and A are the highest classes followed by B and C. Atlas MHG based steady state solar simulators achieve class B, which is practical for all PV module testing under IEC 61215/(61646) requiring steady state solar simulation. Figure 6 shows a custom-designed Class BBA Atlas SolarConstant solar simulator for PV module performance testing

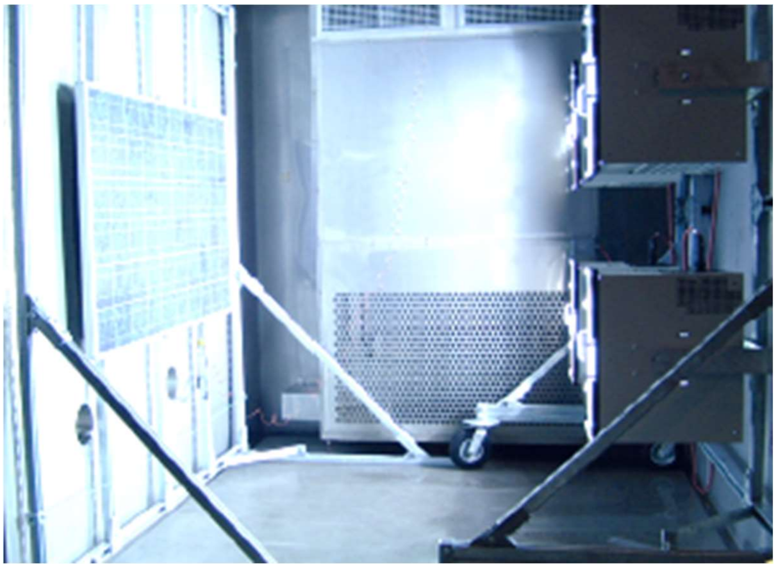

Figure 6: *Customized rack with MHG solar simulator using 4 SolarConstant MHG luminaires.*

Electronics

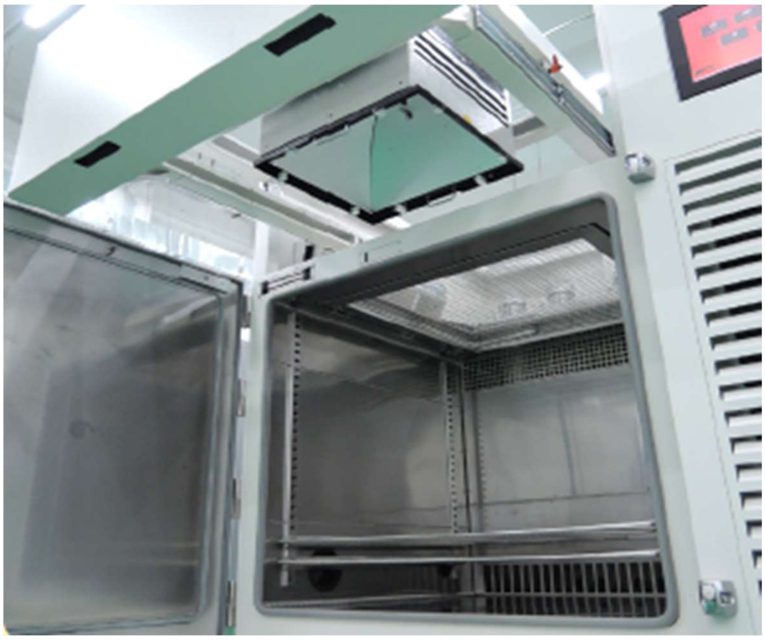

Figure 7: *Customized 1100 l SEC chamber with SolarConstant MHG 4000.*

IEC 60068-2-5 includes three solar environmental test methods (Sa 1, Sa2, Sa3) as well as two weathering tests (Sb1, Sb2; xenon) for electronic products. Sa1/Sa2/Sa3 are so called solar heat load stress tests. All Sa tests are typically performed in small to mid-sized MHG chambers for smaller products and inside Walk-in size MHG chambers for larger/multiple products.

Figure 7 shows a custom designed medium size MHG solar environmental test chamber using one Atlas SolarConstant MHG 4000 on top.

Summary

MHG solar simulators play a key role in durability and performance testing especially in industries such as automotive/transportation, defence, PV Solar, and electronics. Over the past 20 - 30 years, about thirty standards got published where MHG solar simulators such as the SolarConstant MHG series are the first choice over competitive technologies. Today, the MHG solar simulators for their different applications are either integrated on top of climate chambers turning them into SEC, or under the roof of large drive-in, full vehicle/train/aircraft solar test chambers. The spectral irradiance compared to natural sunlight is highly realistic, especially for the visible and IR-radiation parts, which is essential to all solar environmental stress standards with their focus on realistic solar heat load.

References

[1] CIE 241:2020, Recommended Reference Solar Spectra for Industrial Applications.

[2] DIN 75220:1992-11, Ageing of automotive components in solar simulation units.

[3] MIL-STD-810H, Environmental Engineering Considerations and Laboratory Tests, Method 505.7 Solar Radiation, 2019.

[4] IEC 61215-1:2021, Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements.

[5] IEC 61215-2:2021, Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures.

[6] IEC 60068-2-5:2018, Environmental testing - Part 2-5: Tests - Test S: Simulated solar radiation at ground level and guidance for solar radiation testing and weathering.

[7] IEC 60904-9:2020, Photovoltaic devices - Part 9: Classification of solar simulator characteristics.

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