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Coating Surface Temperature During Artificial Weathering: Significance for Lifetime Prediction

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Introduction

The surface temperature of a sample irradiated with natural solar radiation or artificial xenon arc radiation is not only influenced by the environment, but also by its specific material properties such as its color. So far, it has been impractical in weathering tests to measure the sample surface temperature directly. Experimenters have primarily estimated sample surface temperatures based on measurements made with reference thermometers, such as insulated black standard thermometers or uninsulated black panel thermometers, which may, but not always, represent the hottest temperature a surface can achieve in a specific environment under irradiation.

In a weathering test, an inaccuracy in estimating the true sample temperature can significantly influence the evaluation of the aging behavior of the sample. Knowing the actual sample surface temperature allows for a more precise comparison of the effect of different weathering conditions (e.g., natural vs. artificial weathering, or one color vs. another color sample). It also makes it possible to adjust the test parameters of artificial weathering cycles based on the specific sample characteristics, such as the glass transition temperature.

In this article, we present how non-contact temperature measurement can be implemented in artificial weathering to obtain more detailed information about the actual surface temperature during weathering. This method could be used, for example, to determine the activation energies of photochemical degradation processes that can lead to yellowing, fading, or other property changes in samples. Knowing and considering the specific sample temperature leads to better estimations of service life — and, ultimately, a better understanding of artificial weathering.

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Atlas Turns 100!

Celebrating a Century of Product Durability Testing Solutions

Before Hollywood existed, Chicago was the motion picture capital of the world — and Atlas was there, supplying high-intensity stage lighting using a carbon-arc light source. It became apparent that certain textile materials and garments worn around these lights would fade or discolor after a period of time — similar to what happened to the same fabrics when exposed to natural sunlight.

From this problem, the Atlas of today was born in 1915. In a back room experiment with the studio arc lamp, Atlas' founder C.W. Jameson developed the first fading unit, the Solar Determinator (redesigned and renamed the Color Fade-Ometer® in 1919). With the addition of weathering capabilities in 1927, the first patented Atlas Weather-Ometer® accelerated weathering instrument was developed.

Throughout the past century, Atlas has continued to be the leading innovator in weathering, offering a comprehensive network of both testing instruments and outdoor and accelerated laboratory services.

A lot has changed in 100 years, but Atlas' focus has remained the same — providing customers with sophisticated technology and advanced testing solutions to determine how long their products will last. As a result, they can reach their ultimate goals: a quality product, a competitive edge, and a faster time to market.

Altas' Innovations Over a Century

1915
Atlas Founded

1931
South Florida Test Service opens in Miami

1934
Sunshine Carbon Arc Weather-Ometer® developed

1948
DSET Laboratories founded in Phoenix, AZ

1954
First air-cooled xenon-arc weathering device (Xenotest® 150) developed

1958
First EMMAQUA® device introduced

1976

UVCON Fluorescent UV device and SUNTEST CPS, the first flatbed tabletop instrument introduced

1978

Patented Ci Series Weather-Ometers launched

1990s

A decade of innovation: Xenotest® Alpha and Beta; SUNTEST XLS/XLS+; Ci 3000, 4000 and 5000 Weather-Ometers

2004

SUNTEST XXL/XXL+ large flatbed xenon instrument introduced

2008

Right Light™ filter technology introduced for Ci instruments

2009

Ultra-Accelerated Weathering System and UVTest Fluorescent UV device introduced; Solar Test Center opened; Atlas 25+® PV Test Program launched

2010-13

Xenotest® 220/220+ and 440 with XenoLogic™ technology introduced

2014-15

UA-EMMA®/EMMAQUA® and Low-Temperature EMMA®/EMMAQUA® devices launched

...stay tuned for Atlas' next weathering testing innovation!

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Fundamentals of Weathering I

June 10, 2015	Gorinchem, The Netherlands	Presented in Dutch
June 17, 2015	Olten, Switzerland	Presented in German
June 23, 2015	Rosenheim, Germany	Presented in German
July 22, 2015	Mount Prospect, IL, USA	Presented in English
September 29, 2015	Leicester, UK	Presented in English
October 7, 2015	Mount Prospect, IL, USA	Presented in English
October 21, 2015	Ghent, Belgium	Presented in Dutch
October 27, 2015	Boras, Sweden	Presented in English
November 24, 2015	Hildesheim, Germany	Presented in German

Fundamentals of Weathering II

June 11, 2015	Gorinchem, The Netherlands	Presented in English
June 18, 2015	Olten, Switzerland	Presented in German
June 24, 2015	Rosenheim, Germany	Presented in German
July 23, 2015	Mount Prospect, IL, USA	Presented in English
September 30, 2015	Leicester, UK	Presented in English
October 8, 2015	Mount Prospect, IL, USA	Presented in English
October 22, 2015	Ghent, Belgium	Presented in English
October 28, 2015	Boras, Sweden	Presented in English
November 25, 2015	Hildesheim, Germany	Presented in German

Weather-Ometer® Workshop

July 21, 2015	Mount Prospect, IL, USA	Presented in English
September 29-30, 2015	Linsengericht, Germany	Presented in German
October 6, 2015	Mount Prospect, IL, USA	Presented in English

Xenotest® Workshop

September 22-23, 2015	Linsengericht, Germany	Presented in German

SUNTEST Workshop

September 25, 2015	Linsengericht, Germany	Presented in German

Technical Seminar – Automotive Weathering Testing

May 6, 2015	Pune, India	Presented in English
May 11, 2015	New Delhi, India	Presented in English

Technical Seminar – Lightfastness Testing of Textiles

May 8, 2015	Mumbai, India	Presented in English
May 12, 2015	New Delhi, India	Presented in English

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European Coatings Show 2015
April 21-23, 2015
Nürnberg, Germany
Hall 5, Booth #5-344

Elmia Polymer
April 21-24, 2015
Jönköping, Sweden
Booth #A10:03

SNEC PV Power Expo
April 28-30, 2015
Shanghai, China
Booth #W4 100-101

Techtextil 2015
May 4-7, 2015
Frankfurt, Germany
Hall 3.0, Stand #J32

PLAST 2015
May 5-9, 2015
Milano, Italy
Booth #B65

Asia Coatings Congress
May 12-13, 2015
Ho Chi Minh City, Vietnam
Booth #27

Scandinavian Coatings Show
May 19-21, 2015
Gothenburg, Sweden
Booth #F04:52

CHINAPLAS 2015
May 20-23, 2015
Guangzhou, China
Booth #9.5K21 Hall 9.2

Anafapyt Latin American Coatings Show 2015
June 30 – July 2, 2015
Mexico City, Mexico
EQUIPOS Y SERVICIOS WESTEK
Booth #639

Safety Testing Americas
August 19-20, 2015
São Paulo, Brazil

Asia Pacific Coatings Show 2015
September 8-9, 2015
Kuala Lumpur, Malaysia
Booth #J06

Automotive Testing Expo
September 15-17, 2015
Shanghai, China
Booth #4018

testXpo 2015
October 12-15, 2015
Ulm, Germany

ITMA 2015
November 12-19, 2015
Milan, Italy
Hall 07-25, Booth #H113

CHINACOAT 2015
November 18-20, 2015
Shanghai, China

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For a complete list of Atlas shows, visit http://atlas-mts.com/news-events/trade-shows/

Empack Belgium
November 25-26, 2015
Brussels, Belgium

ATLAS • SPEAKS

European Coatings CONGRESS 2015

April 21, 2015
NürnbergMesse, Nürnberg
Convention Centre
Nürnberg, Germany

"Coating Surface Temperature during Artificial Weathering – Significance for Lifetime Prediction"

Presenter: Dr. Florian Feil, Atlas Material Testing Technology GmbH

IEST ESTECH 2015

April 29, 2015
Doubletree Hotel Boston
North Shore
Danvers, MA, USA

"Solar Simulation – Path to a Good Solar/Chamber Integration"

Presenter: Mr. George Coonley, Atlas Material Testing Technology LLC

Asia Coatings Congress 2015

May 13, 2015
Windsor Plaza Hotel
Ho Chi Minh City, Vietnam

"Achieving Service Life Prediction Through Improved Accelerated Weathering Techniques"

Presenter: Mr. Craig Hazzard, Atlas Material Testing Technology LLC

Profiles 2015

June 10, 2015
Hilton Philadelphia
City Avenue Hotel
Philadelphia, PA, USA

"Novel Concept of a Long-Term Durability Test Program for Fenestration"

Presenter: Mr. Scott Zimmerman, Atlas Material Testing Technology LLC

PTS Seminar in Heidenau

June 9, 2015
PTS offices - Pirnaer Straße 37
Heidenau, Germany

"Weather Factors and Lightfastness Testing"

Presenter: Dr. Florian Feil, Atlas Material Testing Technology GmbH

"Standards for Lightfastness Testing of Printings and Printing Inks"

Presenter: Dr. Florian Feil, Atlas Material Testing Technology GmbH

7th European Weathering Symposium EWS

September 16-18, 2015
Congress Center of the
University of Naples Federico II,
Via Partenope 36
Naples, Italy

"The Specimen Surface Temperature in Artificial Weathering – Often Neglected but Invaluable for Durability and Correlation Studies"

Presenter: Dr. Florian Feil, Atlas Material Testing Technology GmbH

21st SLF Congress (The Federation of Scandinavian Paint and Varnish Technologists)

September 18, 2015
Clarion Post Hotel
Gothenburg, Sweden

"Temperature on Surfaces Exposed to Solar Radiation: Calculation and Simulation Based on Environmental Data"

Presenter: Dr. Artur Schönlein, Atlas Material Testing Technology GmbH

Coating Surface Temperature, from page 1

Radiation-Related Increase in Temperature

Solar Radiation on Polymeric Materials

The natural solar radiation absorbed by polymeric materials causes an increase in surface temperature above the ambient temperature. All conditions being equal (insulation, thickness, geometry and orientation of the specimen, climatic conditions such as wind speed, etc.), surface temperatures might differ. The surface temperature depends fundamentally on the proportion of the absorbed radiation [1, 2, 3]:

$$S_{ABS} = \int E_{e\lambda}(\lambda) \cdot \alpha_{ABS}(\lambda) \cdot d\lambda \qquad \text{(Equation 1)}$$

where S_{ABS} is the total absorbed radiation, $E_{e\lambda}$ the spectral irradiance, and α_{ABS} the wavelength-dependent spectral absorption

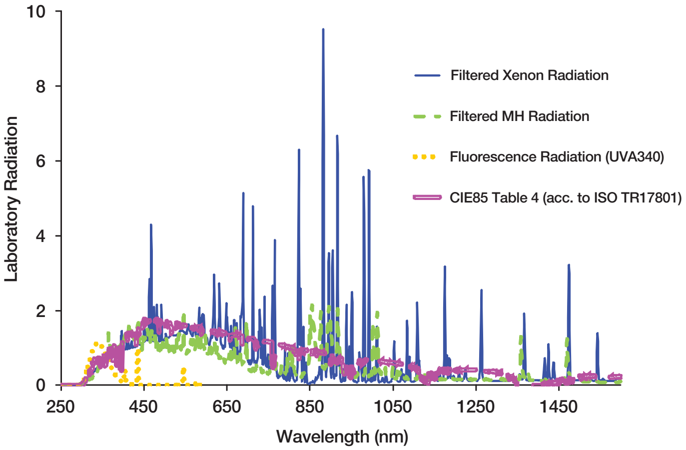

Figure 1: Laboratory radiation sources for the simulation of natural solar radiation compared to the reference sun (CIE85, Table 4 - ISO TR 17801); scaled according to ISO TR 18486 in the wavelength range from 300 nm to 400 nm.

Photochemical degradation processes are initiated based on the spectral sensitivity of the material, primarily due to UV or visible radiation [4]. The speed of chemical reactions is almost always dependent on temperature. For photochemical degradation processes due to solar radiation, the relevant temperature is the surface temperature of the test specimen.

Simulated Solar Radiation on Polymeric Materials

Equation 1 applies for natural and simulated solar radiation. The surface temperature is based on the absorbed radiation (S_{ABS}) of the radiation source used. Filtered xenon and metal halide radiation sources can produce surface temperatures similar to those that occur under the influence of solar radiation (absolute temperatures, temperature differences). Other artificial radiation sources (such as UV fluorescent gas discharge lamps) cause temperature effects on the surface that cannot be compared with the effects of solar radiation (temperatures that are too low or too high, little or no temperature difference between different samples) [1]. This is due to the spectral energy distribution of the artificial radiation source (see examples in Figure 1).

Measurement of Surface Temperature

Each sample may have a slightly different temperature (see [1, 2, 3]). It is not easy to directly measure surface temperatures during natural and artificial weathering tests since the influence of radiation on the temperature sensor itself must be excluded. Therefore, it is currently common practice in weathering testing to estimate the sample surface temperature based on the temperature of the ambient air in the test chamber, or by using the temperature of a white-colored flat surface as a lower reference and the temperature of a black-colored flat surface as an upper reference. These reference temperatures are somewhat easier to measure during weathering tests. It is then assumed that the actual sample temperature is between these two limits or close to the temperature of these references.

There are different versions of these reference temperature-measuring devices, e.g. black standard thermometers (BST) and black panel thermometers (BPT), such as those shown in Figure 2, as well as white standard thermometers (WST) and white panel thermometers (WPT). These sensors are described in various standards (for example, ISO 4892-1, ISO 16474-1, and ASTM G151). However, systematic differences among different sensor types can produce inaccurate results.

A new technology for the direct measurement of the surface temperature in a weathering instrument was introduced a few years ago [5]. In this system, a pyrometer is mounted in the device, and the thermal radiation emitted by the samples is measured (see Figure 3). The temperature is recorded while the samples rotate past the pyrometer. The pyrometer has the following characteristics:

- Temperature range from -20 °C to 150 °C (traceable calibration by means of black-body radiation)
- Spectral range from 8 µm to 14 µm
- Silicon thermopile IR detector
- Accuracy (in the temperature range of weathering tests): 0.6%
- Measurement spot (diameter): 30 mm

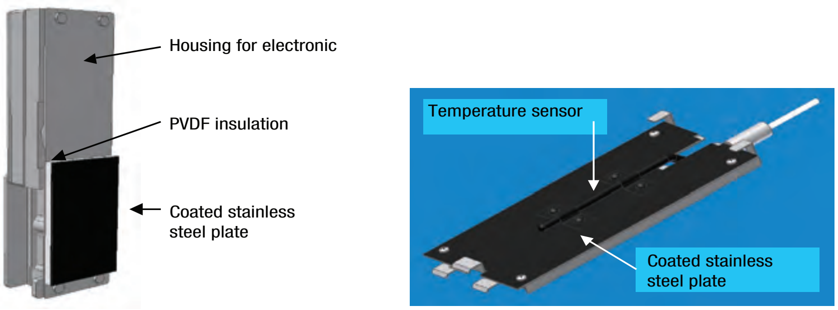

Figure 2: Example of a black standard thermometer (back of the coating is insulated) and a black panel thermometer (back of the coating is not insulated).

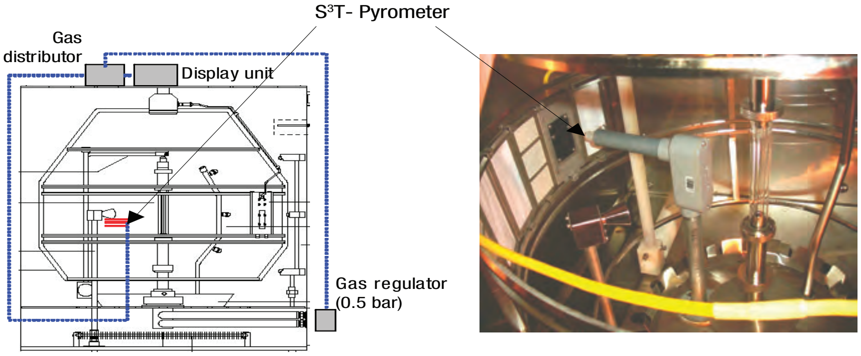

Figure 3: Pyrometer in a weathering instrument used to measure the surface temperature of the exposed samples. The temperature is recorded while the samples rotate past the pyrometer.

The temperature of a given object can only be accurately measured if the emissivity (ε) is in the wavelength range between 8 µm and 14 µm and the pyrometer is adjusted accordingly. The emissivity is the quotient between the radiation emitted by a particular sample and the radiation emitted by an ideal black body of the same temperature. An ideal black body has the emissivity $\varepsilon = 1$, and a perfect thermal mirror has the emissivity $\varepsilon = 0$. The emissivity of a real object is always less than 1. For most organic materials, $0.85 < \varepsilon < 0.95$ is common. Table 1 contains some emission coefficients of typical materials.

Material	ε
Polypropylene	0.97
Planed Wood	0.86-0.90
Black Polymers	0.85-0.95
PVC	0.90-0.93
Rubber	0.95-0.97
Plywood	0.83-0.98
Paint	0.86-0.95

Table 1: Examples of emission coefficients in the wavelength range from 8 µm to 14 µm (see also [5, 6]).

Figure 4 illustrates a surface temperature measurement of colored PVC-coated 1 mm-thick aluminum plates in a weathering device equipped with a pyrometer (see Figure 3). Aluminum is an excellent heat conductor, and the PVC coating is only 5 µm thick. The temperature is measured by a thermocouple on the back of the thin aluminum plate, shielded from the radiation. With these two different methods of temperature measurement, a useful validation of the pyrometer can be performed. For the pyrometer measurements, the emissivity is assumed to be 0.93. Figure 4 clearly shows the temperature difference between the different colored aluminum plates. Figure 5 shows the temperature of the colored PVC-coated aluminum plates measured by the two (thermocouple and pyrometer) techniques for various standard tests. From 45 °C to about 100 °C, similar results are observed for all test methods.

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Coating Surface Temperature, from previous page

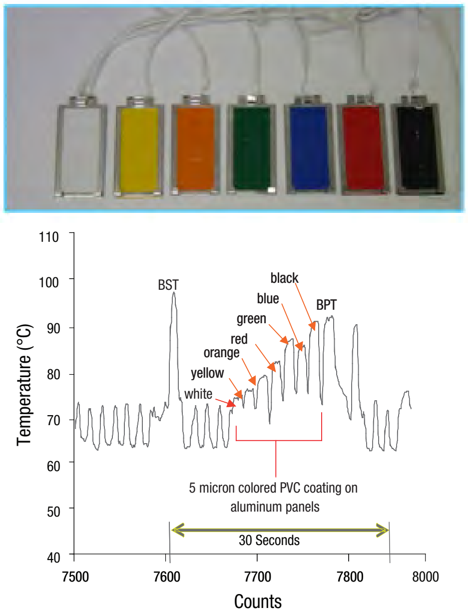

Figure 4: Surface temperature measurement of colored PVC-coated aluminum plates with a pyrometer in a weathering device (see Figure 3).

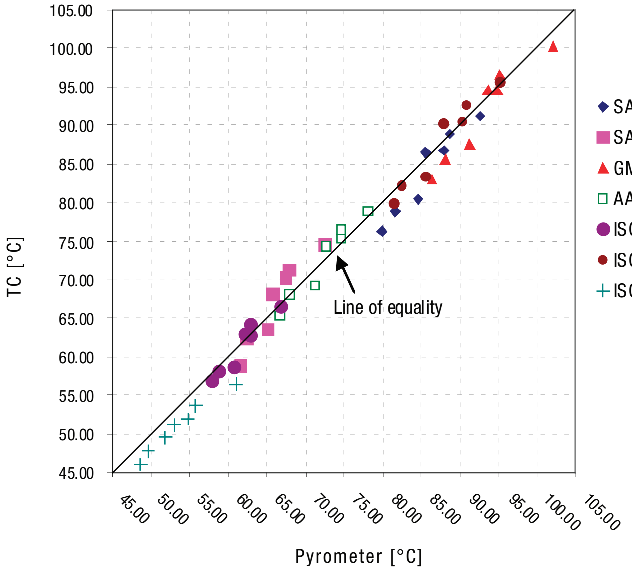

Figure 5: Validation of the surface temperature measured by various standard tests with a pyrometer (x-axis) in an exposure apparatus and a radiation-shielded temperature measurement using a thermocouple (y-axis) behind a thin aluminum plate.

Calibration of Surface Temperature Sensors

Surface temperature sensors as shown in Figure 2 must be calibrated to a recognized national standards body. For the contact temperature measurement process, the surface temperature sensor is calibrated in thermal equilibrium in a liquid bath. In this case, a contact thermometer is used as a traceable standard. A calibration method using a pyrometer has recently been developed. Both calibration methods are described in a newly published European standard (prEN 16465: 2014 [7]).

Applications

The following examples illustrate surface temperature measurements for a variety of flat material samples, including textiles and polymers. The principles can be directly transferred to coatings. Real surface temperatures of coatings are also published in [1].

Surface Temperatures of Textiles

Surface temperature profiles of some textiles are shown in Figure 6 and 7 [8]. The temperature difference of the different colored textiles at the beginning and the end of the exposure is illustrated in Figure 7. The fourth and fifth blue samples (L2 and L4) have significantly lower temperatures than the first three blue samples (B1, G2, and G4). The reason for this could be special pigments or different deposits.

Surface Temperatures of Polycarbonate, Polypropylene, and PMMA Samples

Surface temperatures of transparent, semi-transparent, and opaque polycarbonate samples containing an infrared reflective pigment (61 x 36 x 4 mm) were measured in a weathering device equipped with a pyrometer as described in [7]. Table 2 demonstrates a clear correlation between absorbed radiation and the measured surface temperature. In two convective cooling conditions (noted in columns 4 and 5), the coefficient of determination (Pearson r) is close to 1. The black standard temperatures are well above the near-black opaque samples.

The surface temperatures of solid polypropylene samples (70 x 40 x 4 mm) were measured with specially prepared surface temperature sensors during artificial weathering (see Table 3). Resistance temperature devices (RTDs, Pt-1000) were embedded in the polymer so that no direct radiation irradiated the temperature element. This setup was then calibrated on the surface as described in [7] with a calibration pyrometer under realistic conditions. The surface temperature of the black-colored polypropylene material was significantly higher than the black standard temperature (Table 3, column 4). The temperature of the natural colored polypropylene (Table 3, column 3) was close to the white standard temperature (e.g., for $T_{BST} = 65°C$: $T_{WST} = 48°C$).

Transparent materials (for example, PC, PET, PMMA, Figure 8) represent a special case, where the actual surface temperature is often below the white standard temperature and closer to the ambient temperature [10]. However, the maximum temperature in transparent samples occurs beneath the surface (not at the surface), when exposed to a radiation source [6].

Models for Service Life Estimate

The temperature dependence of the rate of photochemical reactions can be estimated using a modified Arrhenius equation:

$$k = A \cdot I_{eff}^{\alpha} \cdot e^{-\frac{E_a}{RT}} \qquad \text{(Equation 2)}$$

where k is the reaction rate, A is the Arrhenius factor, R is the universal gas constant (8.314 J·Mol^{-1}·K^{-1}), T is the absolute temperature (in K), E_a is the activation energy (in J·mol^{-1}) of the considered property change, I_{eff} is the effective irradiance, and α is a material-specific coefficient.

Due to the lack of a specific traceable chemical parameter or reaction during a weathering test, usually a specific macroscopic property change (such as gloss loss or color change) is taken into account for the Arrhenius equation. For lifetime estimation based on accelerated tests, the ratio of the reaction rate constants under accelerated (a) and use (u) conditions can be applied:

$$\frac{k_a}{k_u} = \left(\frac{I_a}{I_u}\right)^{\alpha} \cdot e^{\frac{E_a}{R}\left(\frac{1}{T_u}-\frac{1}{T_a}\right)} = AF_R \cdot AF_T = AF$$

(Equation 3)

where AF is the general, AF_T is a temperature-related, and AF_R is the radiation-induced theoretical acceleration factor

For lifetime estimation of opaque samples, the surface temperature should be selected. For transparent samples, as mentioned above, the maximum temperature will occur below the sample surface [6]. Other factors that influence the photodegradation are the effective irradiance [11, 12] and the oxygen concentration, which typically are at their maximum at the sample surface and decrease with distance from the surface [13]. This complicates the estimation of service life, especially for transparent samples.

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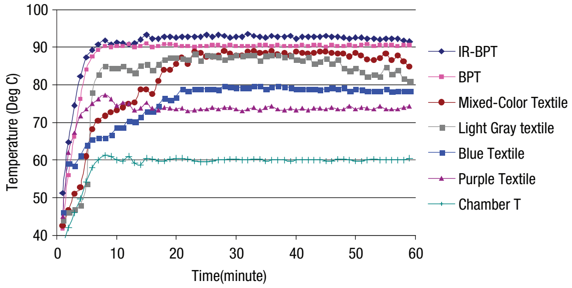

Figure 6: Surface temperature profiles of colored textiles measured with a pyrometer exposed in a weathering device running SAE J2412 (test for automotive interior materials) in the light phase.

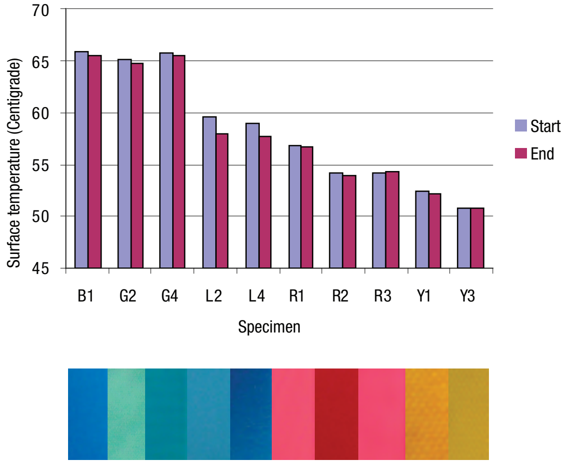

Figure 7: Surface temperature measurement [8] of dyed colored textiles with a pyrometer in a weathering device running AATCC TM 16E.

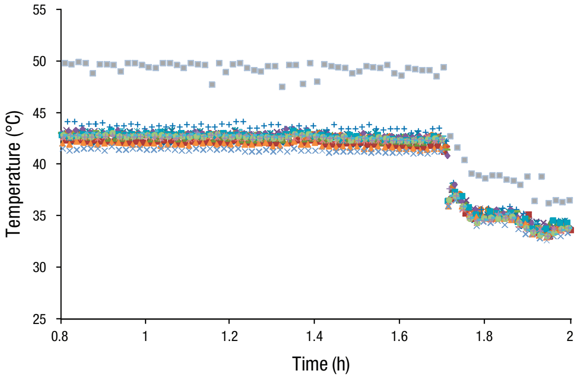

Figure 8: Part of cycle 1 to ISO 4892-2 method A (Atlas Ci4000 Weather-Ometer®). Temperature measurement (with S^{3}T pyrometer) of polymeric samples (y-axis): PC, PET, PMMA (60 x 60 x 2 mm) and a white standard thermometer (gray squares) as a function of test time (x-axis). The temperature drop is due to the onset of a spray phase.

Coating Surface Temperature, from previous page

PC Sample No.	Description	Absorption (%)	$T_{SURFACE}$ (°C)	
			V_{AIR} (high)	V_{AIR} (low)
1	Transparent	20	41	48
2	Light-colored	30	43	52
3	Semi-transparent	64	48	60
4	Semi-transparent	63	49	55
5	Opaque	92	50	65
6	Opaque	96	51	65
7	Opaque	95	51	66
8	Opaque	97	50	64
		Pearson r	0.98	0.97

Table 2: Surface temperatures of transparent, semi-transparent, and opaque IR-reflective PC samples ($\varepsilon = 0.94$). Estimation of the absorbed radiation by means of spectral energy distribution (filtered xenon radiation), spectral transmittance (300-800 nm), and reflection (300-2500 nm). $E_{total} \cong 1200$ W•m^{-2}, ambient temperature = 38°C, $T_{BST} \sim 68$°C (< low air velocity) and 54°C (> high air velocity).

T_{BST} (°C)	E_{UV} (W×m^{-2})	T_{Natur}(°C)	T_{Black}(°C)
65	60	53	69
85	72	73	92
85	48	75	93
65	48	56	75
45	60	39	49
65	60	53	69
45	48	41	52
45	72	34	47
85	60	74	92
65	72	54	68
65	60	53	69

Table 3: Actual surface temperatures of natural and black-colored polypropylene during a weathering test (ambient temperature = 38°C) with variable UV irradiance and T_{BST} [9]. The surface temperature sensors were calibrated according to [7] by a pyrometer (ε of both materials = 0.95).

Determination of Activation Energies

Determination of the activation energy requires experiments to be conducted at different temperatures under otherwise identical conditions, given that the activation energy is temperature independent within small temperature ranges.

Individual weathering tests have to be performed until a certain property change appears, or for a fixed period of time, at a minimum of two different temperatures (for example, at standard condition BST temperature and at 5 K higher and/or lower). All other parameters (irradiance, relative humidity, cycle parameters) must be kept constant, and the sample temperature must be measured. (Note: Under varying conditions, the so-called effective temperatures must be calculated in order to determine the activation energy [11, 12]).

The activation energy can be calculated according to the logarithmic Arrhenius equation (Equation 4) based on two weathering tests, or graphically determined (Equation 5, Figure 9) based on two or more weathering tests. When the natural logarithm of k is plotted versus the inverse of the temperature (1/T), the slope is a straight line with a value equal to $-E_A/R$.

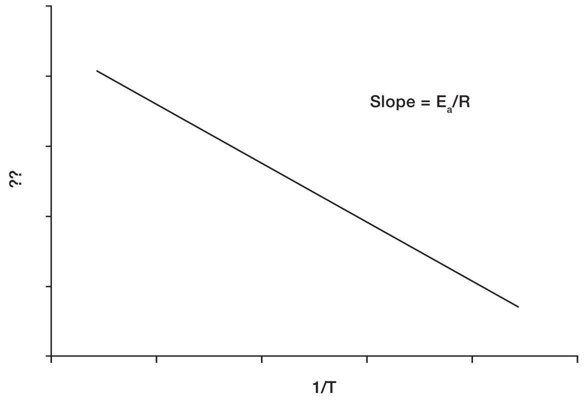

Figure 9: Graphical determination of the activation energy according to Equation 5.

$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_A}{R} \cdot \left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad \textit{(Equation 4)}$$

$$\ln(k) = \ln(A \cdot I^{\alpha}) - \frac{E_A}{R} \cdot \frac{1}{T} \qquad \textit{(Equation 5)}$$

Depending on the polymer and the degradation process, the activation energies of the photodegradation of polymeric materials typically range from 10 to 100 kJ·mol^{-1} [e.g., 10, 11, 14]. However, the number of relevant publications is limited, since the accurate determination of activation energies on weathering and photodegradation of polymers and coatings can be time-consuming and complicated.

If weathering experimenters are willing to invest the effort to make a proper determination of activation energies, it will be beneficial to take the actual sample surface temperatures into account and not rely on rough estimates based on reference temperatures. Use of the pyrometer technology described in this article to measure actual sample surface temperature is much more effective and efficient than the placement of temperature sensors on each individual sample.

Effect of Surface Temperature and Activation Energy on the Service Life Estimation

To demonstrate the influence of surface temperature on acceleration, the theoretical acceleration factors of a test in accordance with ISO 4892-2, cycle 1, for natural weathering in Phoenix, Arizona are calculated. A white standard thermometer (WST) has been chosen to represent a light coating and a black standard thermometer (BST) to represent a dark coating. For theoretical photodegradation pathways, activation energies of 21, 30, 60, and 100 kJ·mol^{-1} are selected. For a light coating and low activation energy, low theoretical acceleration factors are obtained, whereas for a dark coating and a high activation energy, up to 7 times higher acceleration can be achieved. This shows the importance of surface temperature and activation energy for reliable planning and evaluation of weathering tests, and also how big the risk of misinterpretation can be when these factors are incorrectly estimated.

		Phoenix, Arizona		ISO 4892-2, Cycle 1		Theoretical AF		
T_{REF}	E_a (kJ•mol^{-1})	E_{UV} (W•m^{-2})	T_{eff} (°C)	E_{UV} (W•m^{-2})	T_{eff} (°C)	AF_R	AF_T	AF
T_{WST}	21	13.8	34.0	60	45.9	4.3	1.4	5.9
	30		34.5		46.1		1.5	6.6
	60		36.1		46.4		2.1	9.2
	100		37.9		46.7		2.9	12.7
T_{BST}	21		43.2		66.6		1.7	7.5
	30		43.9		67.2		2.2	9.5
	60		46.0		58.0		4.3	18.6
	100		48.3		68.8		9.5	41.3

Table 4: According to Equation 3, calculated acceleration factors (AF indices: AF_R - radiation, AF_T - temperature) of ISO 4892-2, cycle 1 with respect to the natural weathering in Phoenix (T_{REF}, T_{WST}, and T_{BST}) are estimated on the basis of white and black panel temperatures; E_{UV} (300-400 nm) is calculated based on the annual UV exposure in the wavelength range of 295-385 nm); T_{eff} - effective temperatures are calculated according to [11, 12].

Summaries and Outlook

For natural or artificial weathering tests, material surface temperatures depend on the absorption of the incident radiation. Because direct temperature measurements are difficult, reference sensors are used to approximate actual material temperature. Actual sample surface temperatures can differ significantly from these reference temperatures. Examples using textiles and polymers are discussed.

Continued on next page

Coating Surface Temperature, from previous page

The determination of the surface temperature of specimens provides a much more accurate estimate of the stress parameters and material aging rate — and, ultimately, the service life. The use of pyrometers to determine surface temperature is an essential component to facilitate service life studies. Weathering data can be much better understood with better information about these stress parameters.

Knowing the temperature dependence of the material (such as the glass transition temperature) and the corresponding degradation processes, test parameters can be better adapted to individual material requirements and higher acceleration rates may be reliably achieved. In addition, knowledge of the surface temperature allows for a better comparison between different test conditions or cycles [10]. ■

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To learn about Atlas' Specific Specimen Surface Temperature (S³T) System, **click here** to download this flyer.

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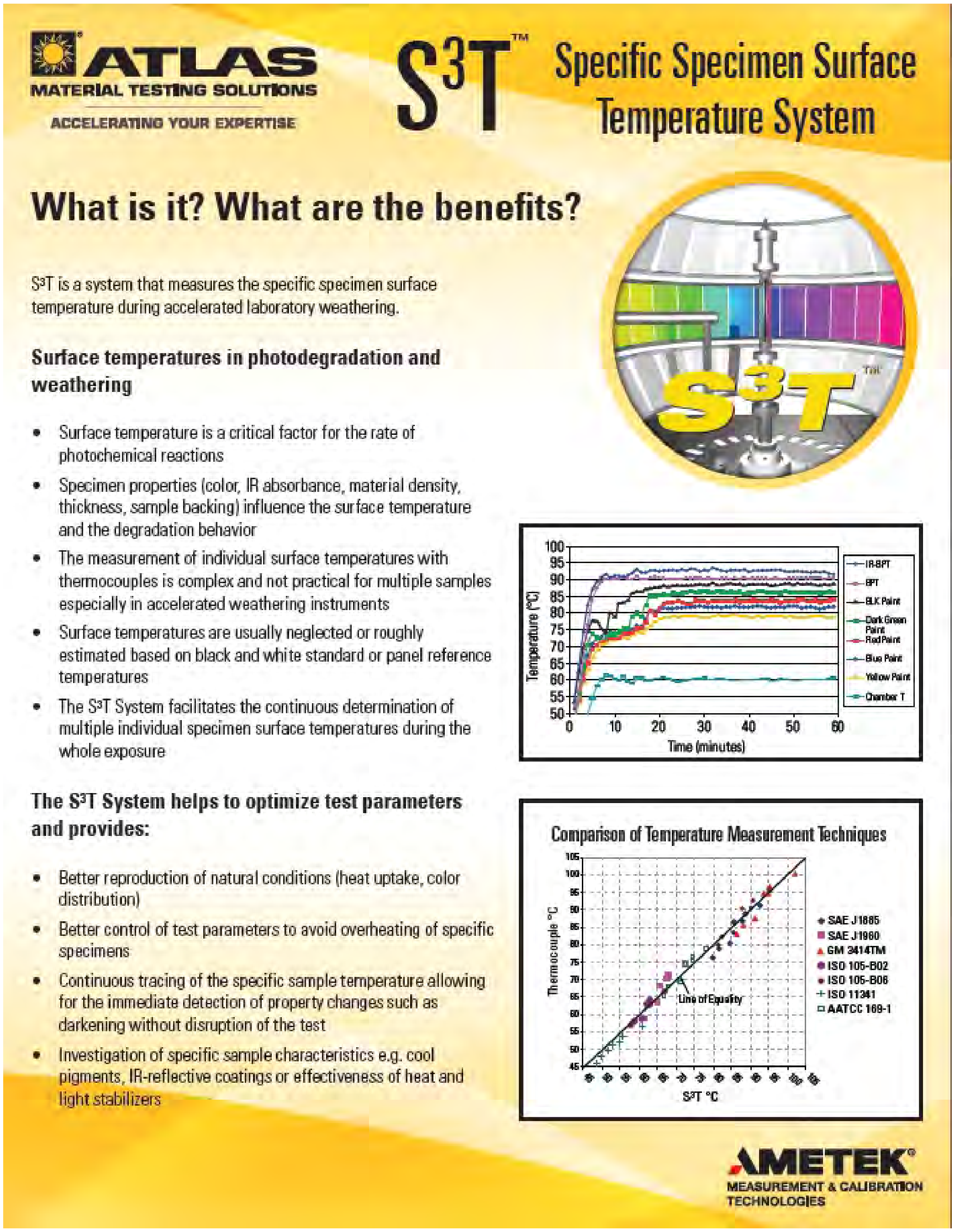

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S³T™ Specific Specimen Surface Temperature System

What is it? What are the benefits?

S³T is a system that measures the specific specimen surface temperature during accelerated laboratory weathering.

Surface temperatures in photodegradation and weathering

- Surface temperature is a critical factor for the rate of photochemical reactions
- Specimen properties (color, IR absorbance, material density, thickness, sample backing) influence the surface temperature and the degradation behavior
- The measurement of individual surface temperatures with thermocouples is complex and not practical for multiple samples especially in accelerated weathering instruments
- Surface temperatures are usually neglected or roughly estimated based on black and white standard or panel reference temperatures
- The S³T System facilitates the continuous determination of multiple individual specimen surface temperatures during the whole exposure

The S³T System helps to optimize test parameters and provides:

- Better reproduction of natural conditions (heat uptake, color distribution)
- Better control of test parameters to avoid overheating of specific specimens
- Continuous tracing of the specific sample temperature allowing for the immediate detection of property changes such as darkening without disruption of the test
- Investigation of specific sample characteristics e.g. cool pigments, IR-reflective coatings or effectiveness of heat and light stabilizers

AMETEK®
MEASUREMENT & CALIBRATION TECHNOLOGIES

Atlas Launches New Low-Temperature EMMA®/EMMAQUA®

Atlas has introduced its latest innovation utilizing "cool mirror" technology — the Low-Temperature EMMA®/EMMAQUA® (LT-EMMA®/EMMAQUA®).

The LT-EMMA/EMMAQUA device delivers more than five years of equivalent radiation exposure as would be received in a standard outdoor testing rack in South Florida in a single year, but with cooler sample temperatures than traditional EMMA/EMMAQUA testing.

The device achieves cooler sample temperatures through a patented cool mirror technology that has very high reflectance in the UV and near visible wavelength ranges, while attenuating reflectance in the longer wavelength visible and IR portions of the solar spectrum.

"LT-EMMA/EMMAQUA is the latest advancement in our growing line of outdoor accelerated devices that are unmatched in the weathering industry," said Richard Slomko, Director of Atlas' Weathering Services Group. "This new technology is ideal for temperature-sensitive materials such as vinyl siding and composite decking. The LT-EMMA/EMMAQUA device is also compliant with ASTM G90."

Slomko added, "We are excited to add the new LT-EMMA/EMMAQUA device to Atlas' accelerated outdoor testing services, which include our traditional, Temperature-Controlled, Moisture-Controlled, and Ultra-Accelerated EMMA/EMMAQUA devices. These services, coupled with our revolutionary Ultra-Accelerated Weathering System, which offers an acceleration factor of up to 63X, put Atlas light years ahead of the competition."

For more information on EMMA/EMMAQUA testing or to request a quote, please contact Chelsea Todd at chelsea.todd@ametek.com or +1-623-465-7356 x103. ■

Key Member of Atlas Weathering Services Team Retires

Atlas congratulates Kathy Eoff on her retirement, effective March 13, 2015. Kathy has been a key member of the Atlas family for 36 years, having held the position of Senior Optics Technician for a large part of her tenure. She has built many strong relationships with both clients and staff, and she will be greatly missed. We wish Kathy well in all her future endeavors.

Any Optic Lab questions going forward may be directed to Erika Wunderlich at our Arizona facility (erika.wunderlich@ametek.com or +1-623-465-7356 x159).

Atlas Test Sites in India and France Receive ISO 17025 Accreditation

Atlas' outdoor test sites in Chennai, India and Sanary-sur-Mer, France have received accreditation from the American Association for Laboratory Accreditation (A2LA) to the requirements of ISO/IEC 17025:2005.

The new scope of accreditation for Chennai and Sanary-sur-Mer includes numerous outdoor and evaluation test methods from organizations such as:

- AATCC (American Association of Textile Chemists and Colorists)
- ASTM (American Society for Testing and Materials)
- DIN (Deutsches Institut für Normung)
- ISO (International Standards Organization)

The **Chennai, India** test site is located in the southeast region of India. The site is characterized by a tropical climate with high levels of sunlight, humidity, and temperature. It provides valuable test data for many industries, such as automotive exterior and interior panels, parts, components, or complete cars (including paint, polymer, textile, and leather); architectural and building products; and consumer durable goods.

The **Sanary-sur-Mer** test site is situated in the Bandol region of France, which has a typical Mediterranean climate. With 3,000 hours of sunlight per year, an elevation of 110 m, average wet time of 2,700 hours, and a proximity to the Mediterranean Sea of only 4 km, the site is used by many European companies for testing a wide range of materials. The test site is also CSTB (Center Scientifique et Technique du Bâtiment) compliant for the testing of building materials.

Atlas operates a worldwide exposure network with 25 outdoor test sites in various climates around the world to help our customers better understand the global performance of their materials durability. For more information, please visit: http://atlas-mts.com/services/natural-weathering-testing-services/natural-weathering-testing-sites/

To request a quote for any of the Atlas test sites, please contact John Wonders at john.wonders@ametek.com or +1-623-465-7356 x101. ■

Sanary-sur-Mer, France test site

Chennai, India test site

Atlas Expands ISO/IEC Accreditation to Include Sensor Calibrations

The optical laboratory at Atlas Material Testing Technology GmbH in Linsengericht, Germany is now accredited according to ISO/IEC 17025:2005 for sensor calibration.

As one of the world's leading material testing companies, Atlas Material Testing Technology offers comprehensive services for natural and accelerated weathering and also produces weathering test instruments.


XenoCal and Xenosensiv sensors

In 2002, Atlas' Linsengericht optical lab was accredited as a testing lab in accordance with DIN EN ISO/IEC 17025:2005 (D-PL-15044-01). Since that time, Atlas' optical lab specialists have expanded the lab's capabilities to include calibration services. In 2014, the German accreditation body DAkkS granted Atlas a quality seal for its calibration services (D-K-15044-01) making Atlas the only calibration laboratory of its kind worldwide capable of calibrating Atlas XenoCal and Xenosensiv sensors.

"The optical laboratory is our quality center," says Laboratory Manager Dr. Joachim Hussong. "Since 2002, our ISO 17025 accreditation only addressed whether our weathering testing instruments delivered conditions according to the testing standards. With our newly expanded scope of accreditation, we now demonstrate competence in both testing and calibrations."

The optical lab in Linsengericht, Germany is accredited according to DIN EN ISO/ IEC 17025:2005:

- As a test laboratory since 2002 (certificate registration #D-PL-15044-01)
- As a calibration laboratory since 2014 (certificate registration #D-K-15044-01)

Accredited testing procedures:

- Measurement of the spectral irradiance of radiators in the wavelength range from 200 to 1,600 nm and determination of derived radiometric and photometric variables
- Measurement of the irradiance of radiators
- Measurement of the spectral transmittance of filters and glasses in the spectral range from 200 to 1,600 nm and determination of derived radiometric and photometric variables

Accredited calibration procedures:

- Calibration of the irradiance measured value of the Atlas Xenosensiv and XenoCal sensors for the spectral ranges 300 to 400 nm, 300 to 800 nm, 420 and 340 nm related to xenon radiation
- Calibration of the surface temperature measured value of Atlas Xenosensiv and XenoCal sensors under consideration of xenon radiation, humidity, and air movement. Procedure according to prEN 16465, method B (see page 17).

New Standard in Development for Black Panel Temperature Calibration

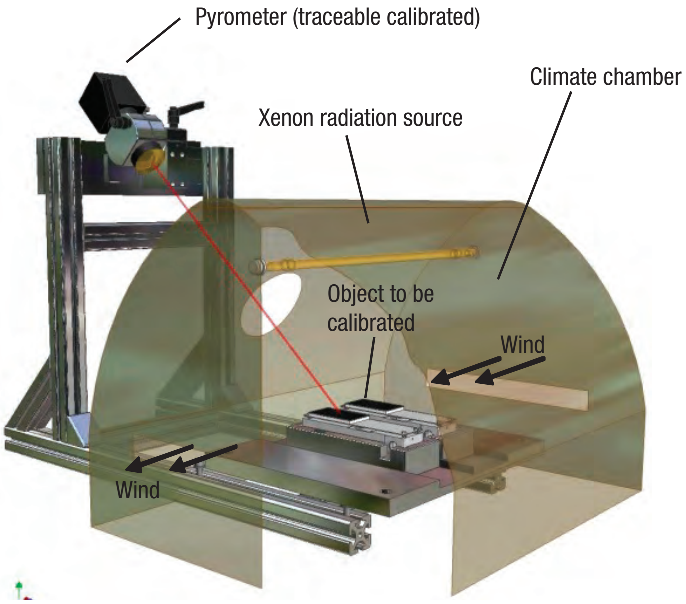
Since 2013, the European Committee for Standardization (CEN) group TC249/WG19 (Light Exposure) has been working on a standard method to calibrate specimen reference temperature sensors such as insulated and uninsulated black panel thermometers (BST/BPT) and white panel thermometers (WST/WPT).

The designation and title of this standard is *prEN 16465, Plastics — Methods for the calibration of black-standard and white-standard thermometers and black-panel and white-panel thermometers for use in natural and artificial weathering.*

The standard consists of two calibration methods: Method A, a contact method, uses a traceable calibrated resistance standard master reference. Method B, a contactless method, uses a traceable calibrated pyrometer. Both master references must be traceable to a national metrological institute such as NIST.

Method A (contact method) consists of the calibration in a liquid bath and additional verification in a test chamber with exposure to a radiation source. The calibration takes place during thermal equilibrium. While this process has historically been used, the calibration part of the process does not take into account the temperature effect caused by variations that could exist between different panels from the influence of the radiation (a xenon lamp, for example).

Method B utilizes a test chamber, a radiation source that generates UV, VIS, and infrared radiation similar to solar radiation (with an appropriate filter system), and a contactless surface temperature device (pyrometer). In this setup, the surface temperature of the thermometer to be calibrated is directly measured with the contactless pyrometer. The calibration conditions for Method B are very similar to the conditions of sensors such as the BPT and BST, as they are used in accelerated weathering instruments. Unlike Method A, this method considers all parameters that affect the temperature of the panel being calibrated.



Schematic diagram of a climate chamber for simulation of temperatures on surfaces exposed to solar radiation

The formal vote on this method will begin in May/June 2015, and EN 16465 will be published as a national standard in early 2016. ■

AATCC Suspends L4 Blue Wool Material Availability

The American Association of Textile Chemists and Colorists (AATCC) has indefinitely suspended availability of the L4 Blue Wool standard reference fabric (Atlas PN 13518600). AATCC says it plans to offer multiple lightfastness grades of blue wool material — including L4 — in the future, however, no date has been announced. As a replacement in the meantime, AATCC advises customers to use the L2 Blue Wool (Atlas PN 12231201).

This unavailability also affects all application kits that previously used L4 Blue Wool, including the following Atlas part numbers:

- 07522000 Kit Textile Ci3000F
- 56079773 Application-Kit TM16-2004
- 07522300 Kit Textile Ci3000F, Two-Tier
- 56080064 Application-Kit TM16-2004

The L4 Blue Wool previously included in these kits will be replaced by the L2 Blue Wool.

At the same time, AATCC has announced that a new lot of L2 material has been validated and is currently being sold. Validation data from AATCC on the lightfastness of this new lot were reviewed and approved by Atlas Standards Management.

If you have any questions about these changes, please contact Richard Slomko, Chairman, AATCC Committee on Lightfastness/Weathering (richard.slomko@ametek.com); Oscar Cordo, Atlas U.S. Standards Manager (oscar.cordo@ametek.com); or Matt McGreer, Atlas Product Manager, Weathering Instruments (matt.mcgreer@ametek.com). ■

CE Mark Now Available for Salt Fog (SF) Corrosion Cabinets

Effective January 1, 2015, all sizes of Atlas' Salt Fog corrosion cabinets (SF260 through SF4200) are available with the CE marking. With the exception of the SO2 Adder Package, all SF accessories and options are also included within the scope of CE compliance.

Atlas SF850

By affixing the CE marking on a product, a manufacturer is declaring, as its sole responsibility, conformity with all of the legal requirements of the relevant European health, safety, and environmental protection legislation in practice. The CE marking signifies that the product complies with all essential EU directives* or EU regulations, and allows for free movement and sale of the product throughout the European Economic Area.

A full set of rigorous test protocols have been conducted on the SF cabinets following electrical and safety test standards, including directives on low voltage, EMC, Restriction of Hazardous Substances (RoHS), and Waste Electrical and Electronic Equipment (WEEE), as well as the applicable EN 61000 and IEC/EN 61010 series of standards.

Please contact your local Atlas sales representative for more information on our corrosion testing equipment. ■

**EU directives contain the essential requirements and/or performance levels and harmonized standards to which products must conform. Harmonized standards are the technical specifications (European Standards or Harmonization Documents) established by several European standards agencies, including CEN (European Committee for Standardization) and CENELEC (European Committee for Electrotechnical Standardization).*

First Solar Successfully Completes Atlas 25^{+}® Testing Program

Atlas is pleased to announce that First Solar, Inc. has completed the rigorous Atlas 25^{+}® Comprehensive PV Durability Testing program and received test result certification from Atlas' partner SGS, the world's leading inspection, verification, testing, and certification company.

The Atlas 25^{+} protocol is a proprietary multi-dimensional durability test program designed to subject photovoltaic modules to the environmental degradation stresses that can be expected over long-term service. It provides manufacturers with the data they need to demonstrate long-term durability and to support warranty and performance claims, while reducing the costs associated with aftermarket product failure.

The Atlas 25^{+} program exposes solar panels to a series of stresses, including UV-A/UV-B exposure, salt spray corrosion, condensing humidity, solar/thermal humidity cycle, solar/thermal humidity freeze cycle, Arizona and Florida solar tracking — including peak summer — and initial, final, and multiple interval measurements. In order to receive SGS certification, modules are required to have less than 8% degradation over the testing period.

"As part of the Atlas 25^{+} independent testing program, solar panels are exposed to harsh weather conditions similar to those faced during their lifetime," said Richard Slomko, Director of Atlas' Weathering Services Group. "First Solar was able to achieve outstanding results with the Atlas 25+ program. We are extremely pleased that the world's leading thin-film PV manufacturer chose to utilize our unique PV durability testing program to confirm module suitability for long-term operation in the world's harshest climates."

Slomko added, "The value of our program to the industry can be measured by the growing list of leading module manufacturers that have sought our testing services. First Solar joins a prestigious group of PV industry leaders such as SunPower, LG, and Suntech, which have passed the Atlas 25^{+} testing protocol and use the Atlas 25+ mark to promote the efficiency and durability of their PV modules." ■

Completion of the Atlas 25^{+} Program provides test data that would otherwise be unattainable with current test methods.

Reporting of results after each measurement set and a final report details all data, images and analyses at the end of the one year sequence.

Outdoor solar tracking in subtropical South Florida and Arizona Sonoran desert

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