Quick Links

Drawing on decades of weathering leadership and expertise, the Atlas Consulting Group provides in-depth consulting services that assist you in developing and applying the best weathering test methods and strategies for your products. ***Atlas Weathering Consulting Insights*** offers interesting and valuable information on a variety of topics relevant to long-term durability testing.

Weathering Testing 101 - Back to Basics
The Question on Everyone's Mind

This issue of the Atlas Weathering Consulting Insights Newsletter is the fourth and final installment of a four- part series that has briefly addressed four of the most frequently asked questions that the Atlas Consulting Group receives in regards to weathering testing.

"How does the temperature influence my laboratory weathering test?" is a frequently asked question. The sample surface temperature is an often-neglected factor in accelerated weathering. Frequently, most planning and evaluation is done based solely on the irradiance and its spectral distribution. However, temperature effects can have a significant influence on acceleration and the degradation pathway too. In fact, temperature effects are very often the reason for poor correlation (see ISO 4892-1) to outdoor exposures when only radiant energy (light dose) is considered.

Two main effects should be considered regarding the temperature in weathering testing:

1) Increasing the temperature increases the degradation rate (Arrhenius principle)
This also applies for photochemical degradation reactions. The extent of degradation depends on the material and the aging mechanism. A rule of thumb says that a temperature increase by 10 K (10°C) doubles the reaction rate. This rule can be used if there is no detailed information about the degradation process. Note: the real temperature influence might deviate but is material specific.

The hotter, the faster! must be advantageous, right? One might think so, but that is not always the case. So, what keeps us from just arbitrarily increasing temperature to achieve additional acceleration? The answer is in the second temperature effect:

2) Increasing the temperature can change the degradation process
The most important phase transition for technical polymers is defined by the glass transition temperature (T_g). The glass transition temperature defines the temperature at which an amorphous or semi-crystalline material turns from a hard and brittle glassy state into a viscous rubbery state. Since molecular processes, like diffusion, are different below and above the glass transition, the whole degradation process can be completely different. Typical technical polymers have glass transition temperatures ranging from -20 °C (polyolefins) up to 150 °C (polycarbonates) and higher. To simulate the degradation in their end-use environment it is important that the state of the polymer is the same in the accelerated test. For some materials, such as PMMA and polyurethanes, the glass transition temperature is in the range of realistic surface temperatures in the field and under laboratory conditions. Particularly here, special care should be taken in laboratory weathering to meet the conditions of field exposures. If not, one test can be above and the other below the T_g which may negatively affect the correlation.

The knowledge of the specimen surface temperature in both its end-use environment and in the accelerated test supports realistic testing and the interpretation of the test data. In outdoor exposures, the specimen surface temperature under solar radiation depends on the absorption of the sample, the ambient conditions, and the thermal conductivity and capacity of the sample itself. Figure 1 shows the daytime distribution of ambient air temperature and Black and White Panel Temperature (BPT/WPT) in Phoenix, Arizona.

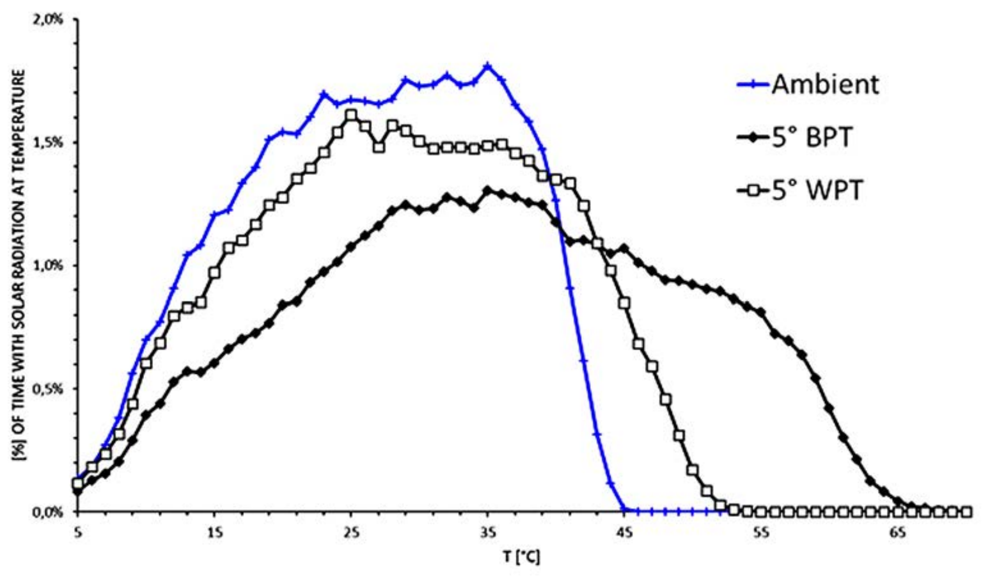

Figure 1: Temperature histograms: distribution of ambient air temperature, BPT and WPT in Phoenix, Arizona for the period 2008-2012 (Source: Atlas DSET Laboratories)

Most test specimens under solar load are likely to have surface temperatures between ambient temperature and WPT (transparent samples) or between BPT and WPT (opaque samples). The mounting of the sample, either open backed or with an insulating back, can have a significant influence on the surface temperature and therefore, its degradation behavior. Thus, for reliable weathering testing, it is crucial to consider these effects in the test parameters.

In rotating rack instruments like the Atlas Ci Weather-Ometer® or the Xenotest® instruments, the test specimen can be exposed either with or without a backing. The use of a backing, and the properties of the backing, will influence the surface temperature. For example, the difference in the surface temperature under standard conditions (ISO 4892-2 Cycle 1) of backed and unbacked transparent PMMA plates can be up 14 K (14°C) if a black painted metal plate is used as backing.

Sample	unbacked	black painted substrate	stainless steel substrate
$T_{Surface}$ [°C]	41	55	50
PMMA			

Table 1: Surface temperature [°C] of transparent PMMA samples during the dry phase of ISO 4892-2 Cycle 1 (60 W/m² (300 – 400 nm); CHT = 38°C, BST = 65 °C) in a Ci4000 Weather-Ometer® with S³T pyrometer and Boro-S/Boro-S filter system (Source: Atlas)

Considering the effects of temperature on photo-chemical degradation, there can be a large influence on the test results from two different backings following the same test cycle. Therefore, for reliable service life estimates it is necessary to consider the surface temperature and to simulate realistically these effects in the accelerated test. Side note: In flatbed instruments, the samples are mounted on a sample tray. The influences of the thermal conductivity and the sample backing on the surface temperature, and thus the sample degradation, might not be realistically simulated. Therefore, testing results in flatbed instruments may deviate from the results in rotating rack instruments unless compensated for.

Specific surface temperatures are hard to predict. They can vary depending on radiation source, material properties, and ambient conditions. Therefore, it is not possible to predict specimen surface temperatures just based on ambient or CHT and BPT/BST without additional knowledge of the sample behavior. Sometimes WPT/WST sensors are closer to the sample properties and can give additional information. However, measuring the surface temperature of specific samples either with thermal sensors or non-contact pyrometers (such as the Atlas S³T Specific Specimen Surface Temperature System) gives the most information and provides for data interpretation with the highest confidence.

If you are not sure about the appropriate sample mounting and its influence on its thermal behavior, or if you need support in setting up surface temperature measurements, we are here to help. The Atlas Consulting Group can assist you in answering these questions. We can also help you select the appropriate standards or develop the test cycles, test methods or complete testing programs that are appropriate for both the product you are testing and its intended end-use environment(s).

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