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.

Estimating Laboratory Weathering Test Acceleration Factors

What you can do when standard test methods offer no guidance on equivalence to outdoor exposures

Oftentimes, as part of laboratory weathering test planning, there is a need for an estimate of the acceleration factor (AF), i.e. how much faster is the lab test over real-time outdoor weathering? Although the question is simple, the answer can be quite complicated. In short, the following must be kept in mind regarding acceleration factors:

- They are highly specific to material chemistry and product design
- They are meaningful only if there is correlation between the tests
- They apply only to a specific measurement parameter, such as color change
- They are valid only for a specific material(s) in a specific set of laboratory and outdoor exposures conditions

Determining AF's requires both laboratory and outdoor exposure data at intervals over a meaningful time period, e.g., until failure. However, the reality is that oftentimes this data simply does not exist, particularly for new materials, formulations or product designs (hence the need for the laboratory accelerated tests). So what can we do?

The easiest approach is not always the best approach

Usually, the first approach that many take is to ignore the above points and simply determine the lab test time it takes to deliver an equivalent radiant energy dose outdoors, particularly in the ultraviolet region, to derive a generalized "theoretical acceleration factor." This approach has some basis for strictly photolytic chemistry, but the reality is that most polymer degradation mechanisms are also affected by temperature. We often see that the UV dose-model underestimates the actual test acceleration by up to twofold or more. However, it sometimes can provide a "worst-case" estimate for test acceleration and therefore, duration.

In this case, an Arrhenius-weighted photolysis model can be used to refine the estimated test acceleration. This method requires determining steady-state "effective" irradiance and temperature values of both the laboratory test (which may involve cycles of the stresses) and the outdoor location (which always contains daily and seasonal cycles) as shown in Figure 1, as well as estimations of the activation energies.

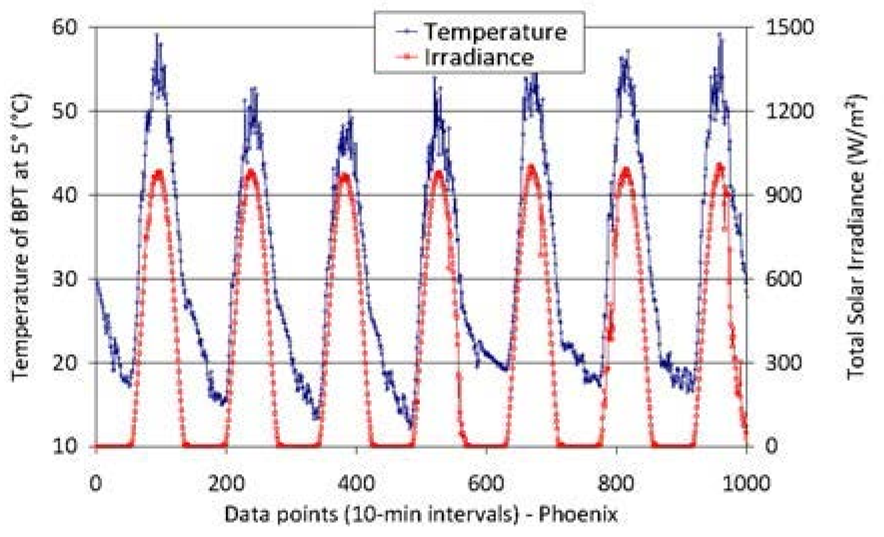

Figure 1 - Temperature and irradiance changes of a typical week in Phoenix, Arizona

For degradation mechanisms which also involve moisture, additional modeling terms can be added, which can make the calculations quite complex. In all of these models, detailed time-resolved weather parameter data is required to determine the effective terms. We typically use the data parsed at one minute intervals for both the outdoor and laboratory tests over the duration of respective exposures.

With many products such as composites or laminate structures, physical weathering due to temperature cycling is in addition to any chemical changes. In such cases, physical models such as Coffin-Manson for thermo-mechanical cyclic fatigue stress can be combined with the photolytic and temperature effect equations, for example. The Atlas Consulting team developed such a method to combine the Arrhenius model and the Coffin-Manson model.[1] This combined method allows us to design and model test cycles which accelerate degradation from both chemical and thermo-mechanical processes in the proper ratio.

Linking to field data and model validation

Some mathematical and empirical models allow estimating theoretical acceleration factors by comparing specific stresses in accelerated tests with field data. The theoretical acceleration of photo-chemical degradation processes of materials by increasing irradiance and temperature can be described by a modified Arrhenius model.[2] The physical stresses of two tests under cyclic stress conditions can be compared using the Coffin-Manson model.[3] Increasing the temperature and the irradiance to accelerate the photo-chemical degradation will most likely also change the physical stresses and vice-versa. Designing a test which accelerates photo-degradation and which increases the physical stress in the same ratio is not trivial.

Putting the models to the test – A case in point

One Atlas Consulting project involved the testing of a new-technology automobile panoramic glass roofing system. Laboratory exposures were performed in a large scale solar/environmental chamber. Multi-year outdoor exposures were performed in hot dry-desert and hot-humid environments in the Atlas EverSummer program, alternating respective exposures between northern and southern hemisphere locations for maximum annual exposure.

Mathematical models were created for the theoretical temperature-weighted light-induced degradation test acceleration and for thermo-mechanical stress of the laminate system. At a little over 1-year outdoor exposure, the property changes and acceleration factors of the laboratory test were in very close agreement for the hot-humid climates and reasonable for the hot dry-desert ones, indicating either a refinement of the lab test cycle or estimated activation energies was required. Test data for years two and three will be used to further refine the current product-specific models.

If you observe aging behavior in the field which you don't observe in classical weathering tests and which might arise from cyclic stresses, contact the Atlas Consulting Group at atlas.info@ametek.com (US) or atlas.info@ametek.de (Europe) to help you. We understand how to optimize weathering test parameters, or combine tests, to reproduce complex degradation mechanisms as well as model the estimated test acceleration for your products.

1. F. Feil, D. Dumbleton, Optimizing Weathering Experiments for the Reproduction of Simultaneous Photochemical and Physical Degradation Pathways, presented at the 6th European Weathering Symposium, 11th-13th September 2013, Bratislava, Slovak Republik.
2. O. Haillant, D. Dumbleton, An Arrhenius approach to estimating organic photovoltaic module weathering acceleration factors, Sol. Mat. 5 (2011) 1284-1292.
3. R. Weglinski, Highly accelerated stress screening for air-cooled switching power supplies Part 1 Understand stress test methodology, White paper: TW0058, February 1, 2007, TDI Power. http://www.tdipower.com/PDF/white_paper/hass.pdf, last accessed on October 30, 2013.

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