

# SunSpots®

Spring 2006

## Polymer Weathering: A Mix of Empiricism and Science

By Dr. Olivier Haillant, Scientific Consultant, Atlas MTT GmbH

### Accelerated Artificial Weathering— A Century-Long Story

Among the environmental parameters influencing the degradation of organic materials, it is daylight, combined with the effect of heat and atmospheric oxygen, that acts as the main parameter of stress in outdoor conditions. [1] When a reasonable amount of daylight passes through windows, indoor conditions can also play a degrading role, primarily affecting the appearance of the material, and are given a lot of attention in the conservation field. [2] Even fluorescent light, usually used to reproduce daylight, was revealed to be potentially damaging. [3] Strictly speaking, only complete darkness would prevent the occurrence of photochemical reactions.

The aging of organic materials has long been acknowledged as a natural and universal phenomenon (metals, glass, minerals and other inorganic materials age as well). It was almost a century ago that the first example of artificial photo-aging was witnessed in the motion picture industry when textiles and garments worn by actors were found to fade during their exposure to carbon arc light, then used as stage lighting. [4]

Despite the early efforts to develop normalized static exposure sites to reproduce the effects of climatic factors on organic materials (e.g., North Dakota site in 1906 for coatings, which eventually moved to Florida), it was only in the '40s that the detrimental effect of light on those polymeric materials became a serious concern to engineers of the plastics industry. In their quest to provide an adapted answer to that issue, two approaches could be discerned: either considering the weathering as a global process



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## AtlasShows

# 2006

### **Forced Degradation (Large Molecule)**

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San Francisco, California, USA

### **ROMPAINT**

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### **SAE**

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Detroit, Michigan, USA

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April 4–7  
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April 7  
Pittsburgh, Pennsylvania, USA

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April 26–29  
Karachi, Pakistan

### **FOCUS**

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### **Testing Expo**

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Stuttgart, Germany

### **Plastic Printing Packaging Pakistan**

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### **Plastics for the Industry**

May 10–11  
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### **Plastex 2006**

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### **Boya/Paint**

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### **Sink or Swim**

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### **Intern Eng Trade Fair**

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### **Coatings for Plastics**

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Instruments Exhibition  
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June 29–July 1  
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### **MSV 2006**

**(48th Intern Engineering)**  
September 18–22  
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### **Eurocorr**

September 24–28  
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### **International Plovdiv**

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### **Korea Autoparts Accessory Show**

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### **Eurocoat 2006**

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### **HET**

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### **IFAI**

October 31–November 2  
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### **ICE**

November 1–3  
New Orleans, Louisiana, USA

### **ITCE**

November 9–12  
Cairo, Egypt

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affecting the service properties of a material or understanding the weathering as the result of chemical reactions at the molecular level accounting for the loss of the material properties.

## One Field, Two Approaches

The oldest and most widely used approach is sometimes referred to as conventional or empirical, as it is driven by two empirical principles [2, 5]:

- All the physical and chemical stresses occurring in real conditions should be reproduced in laboratory tests, at their exact level in simulation conditions.
- The degradation criteria are based on the evolution of a material property.

Therefore, with this approach, the polymeric material is considered as a macroscopic system presenting service properties that are affected under the influence of weather, telling nothing about the underlying involved chemistry. [6]

Back in the '50s, it made sense to set up laboratory tests and interpret the results on the basis of that approach—it was more cost effective than a deeper investigation at the molecular level, quicker, and seemed to be about as reliable. Moreover, an acceleration in testing was achieved under simulated conditions as compared to static outdoor weathering by continuously running the instrument.

More than 50 years later, considerable enhancement in the control of weathering parameters in laboratory instruments together with more accurate evaluation techniques have increased the reliability of accelerated tests in predicting service lifetimes. However, despite these improvements, the success of the empirical approach is regularly shadowed by examples of catastrophic failure—e.g., the delaminating of paint systems in the automotive field—that were not predicted from accelerated laboratory tests. This pushed most paint producers to rely exclusively on dramatically long outdoor exposure tests to evaluate new coating formulations [7], despite the fact that these early laboratory tests were flawed (i.e., unnatural wavelengths and intensities of UV light) and based on erroneous assumptions. Such drawbacks show the limits of the conventional approach (e.g., that one test condition is not appropriate for all materials and environments) and the need to complement it with a deeper understanding of the weathering phenomenon, in other words, a more scientific approach.

In the mid '70s, when analytical techniques adapted for the study of the solid state at the molecular level became cheaper, faster, and easier to use, a more precise investigation of the chemical processes involved during the aging of polymers became the main focus of a few research laboratories. It has been recognized that the complex chemical phenomena accounting for physical deterioration should be identified at the molecular or supramolecular level. [8] In this so-called “mechanistic” approach, the degradation mechanism of a polymeric material is examined in its final formulation and after every processing operation.

## Photochemical Aging at the Molecular Level

It is generally accepted that the main objective of studies in the field of accelerated weathering is to “predict” the permanent effect of the most important stresses—i.e., the effect of UV and heat (both originating from daylight), water (neutral or acidic), and atmospheric  $O_2$ —more or less combined with the influence of mechanical stresses. Other physical and chemical environmental factors, such as reactive atmospheric pollutants ( $O_3$ ,  $SO_2$ ,  $NO_x$ ), biological reactants (microorganisms, bird droppings), and high-energy radiations are secondary factors, whose impact on materials aging is only significant in very specific situations.

The study of the chemical evolution of several classes of polymers exposed outdoors has led to the recognition of the photochemical processes involved in the aging of any polymeric material, such as:

- Photooxidation of the matrix, i.e., an oxidation induced by the combined effects of

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- daylight and atmospheric oxygen;
- Non-oxidative photolysis of the matrix, i.e., a transformation due to the effect of daylight;
- Hydrolysis of the photooxidation products formed in the matrix, i.e., a transformation caused by the conjugated effects of heat and water (in the gaseous or liquid state);
- Formation of yellowing substances (yellowing through absorption) and their subsequent bleaching;
- Formation of fluorescent substances (yielding yellowing through emission) and their secondary photooxidation;
- Transformation of additives (e.g., stabilizers, dyes, pigments, and anti-fog and anti-static agents).

The relative importance of each specific process should be established by analytic techniques, especially by means of in-situ spectrophotometric techniques carried out in the solid state. Each chemical pathway has its own macroscopic consequence on the material integrity. Photochemical oxidation and sometimes oxidative hydrolysis of the matrix is controlling the mechanical properties through chain scissions, and partly controlling the appearance properties (gloss) through superficial micro cracking. [9] Photolysis, yellowing,

bleaching, fluorescent compound formation, and their photooxidation all contribute to appearance changes that could involve different processes. [10] Transformation of additives alters their functional efficiency particularly the fading of colored additives or the formation of precursors leading to yellowing resulting in optical changes. [11]

Therefore, evaluation of appearance (or optical) change by colorimetric methods gives a global measure resulting from the addition of different macromolecular processes. As those processes have their own kinetics (Figure 1) and acceleration factor, the use of colorimetry to predict service lifetime from accelerated tests may lead to errors if more than one process is involved in the appearance.

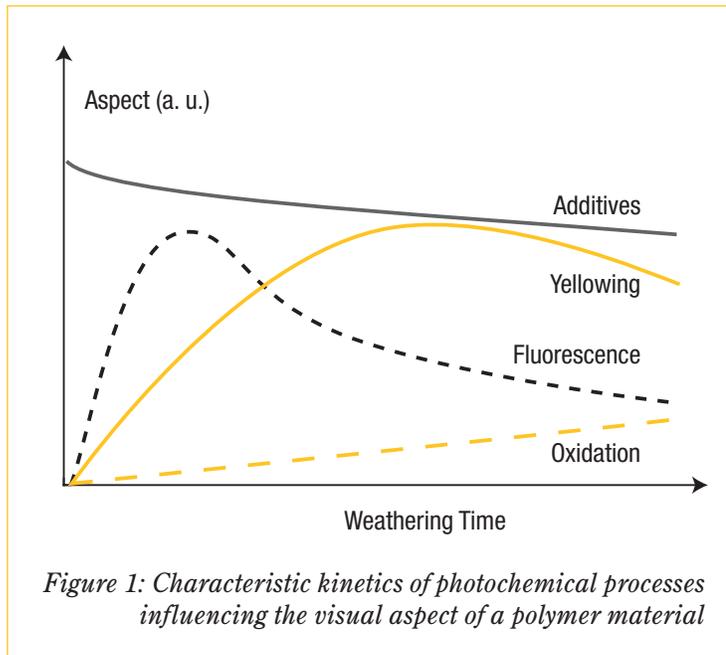
## The Control of Relevance Based on Chemical Analysis

One statement of the mechanistic approach stipulates that the photochemical aging observed during any accelerated photo-aging or weathering test

should involve the same “mechanism” as in natural weathering to assess its representativity or relevance (the next section will discuss in detail the relevant character of an accelerated test). Yet, what is to be understood by mechanism?

The photooxidation mechanism description based on “kinetic schemes” involving elementary processes is still too complex to be useful; moreover, it is theoretically unacceptable since polymer oxidation could not be handled by conventional homogeneous kinetics, heterogeneities appearing at each reaction level (on the macromolecular chains, in the amorphous zones of the matrix, in the complete solid state). The most useful way to describe polymer photooxidation would be the following sequential presentation [12]:

- The first sequence involves the formation of hydroperoxides. This formation proceeds as a chain reaction, the actual length of which is difficult to determine. Photo-initiation could occur via the activation of chromophores, either located on the macromolecular chain or present as impurities in the polymer formulation, which are able to supply



radicals in a photochemical way. At this stage, the chain reaction can be terminated through the recombination of radicals.

- The second sequence involves the thermal or photochemical decomposition of hydroperoxides into intermediate products. This can be either a one-step reaction or a multi-step reaction, when instable intermediate products decompose spontaneously into other intermediate products (e.g., the decomposition of alkoxy radicals into a ketonic compound, either spontaneous or assisted by  $\cdot\text{OH}$ ).
- The third sequence involves the photochemical transformation of intermediate products and the accumulation of final inert products in the polymeric matrix.

The mechanistic approach is based on a useful description of a photooxidation reaction pathway rather than the analysis of reactive species, such as excited states, radicals, or vibrationally excited products, which consists of the following steps [13]:

- Identification of the most important intermediates, such as hydroperoxides, and the photochemically or thermally unstable decomposition products of hydroperoxides;
- Determination of the transformation pathways of the main intermediates (photochemical, thermal, hydrolytic);
- Identification of the main final inert products which accumulate in the matrix, including the so-called critical photoproduct, which should:
  - Account for the main degradation pathway of the matrix and therefore be formed as a consequence of a chain scission process;
  - Be a final and stable product which accumulates in the matrix. Therefore, it cannot be a yellowing product or a low molecular weight product;
  - Accumulate linearly with exposure time until the complete loss of the physical properties. Since such loss occurs after a very low extent of chemical evolution, the critical photoproduct is formed during the very early stages of photooxidation.

For practical reasons, our understanding of the photooxidation mechanism can thus be based on the identification of the final products during natural weathering and artificial aging. This approach is safe when the photooxidation mechanism is thoroughly understood, i.e., based on analytical studies of the long-term aging in natural and laboratory conditions.

## The PVC Photooxidation Mechanism—When Processes Compete

A fairly good example of the understanding gained through the mechanistic approach is the depiction of the photooxidation mechanism of the natural polyvinyl chloride which is now widely accepted. [14, 15] It consists of three competitive reaction pathways, which clearly shows that the mechanical damage occurs from a mechanism very different from the one involved in the change of appearance.

The first pathway is a photolytic process, i.e., occurs to a noticeable extent in oxygen starvation conditions (Figure 2). It consists of a chain dehydrochlorination process (loss of HCl molecules) due to the homolytic cleavage of a Carbon-Chlorine covalent bond, weakened by its proximity to two conjugated Carbon-Carbon double bonds. As a result of this autocatalytic process, polyenic structures of increasing length absorbing at longer and longer wavelength (i.e., smaller and smaller frequencies, denoted by “ $\nu$ ” in the figure) are formed. From seven consecutive C-C double bonds, an absorption in the visible range occurs and cause the PVC to discolor (from yellowing to browning to darkening depending on the polyenes distribution lengths).

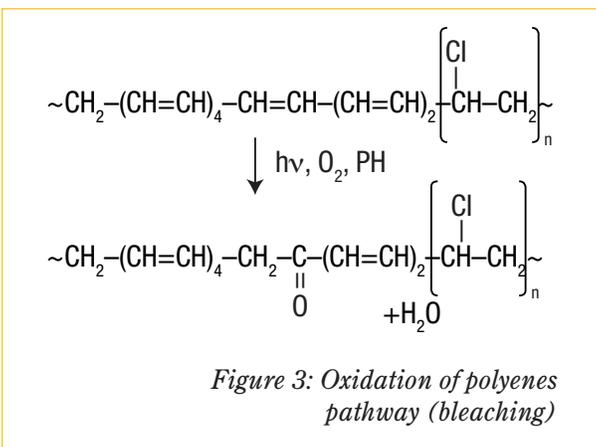
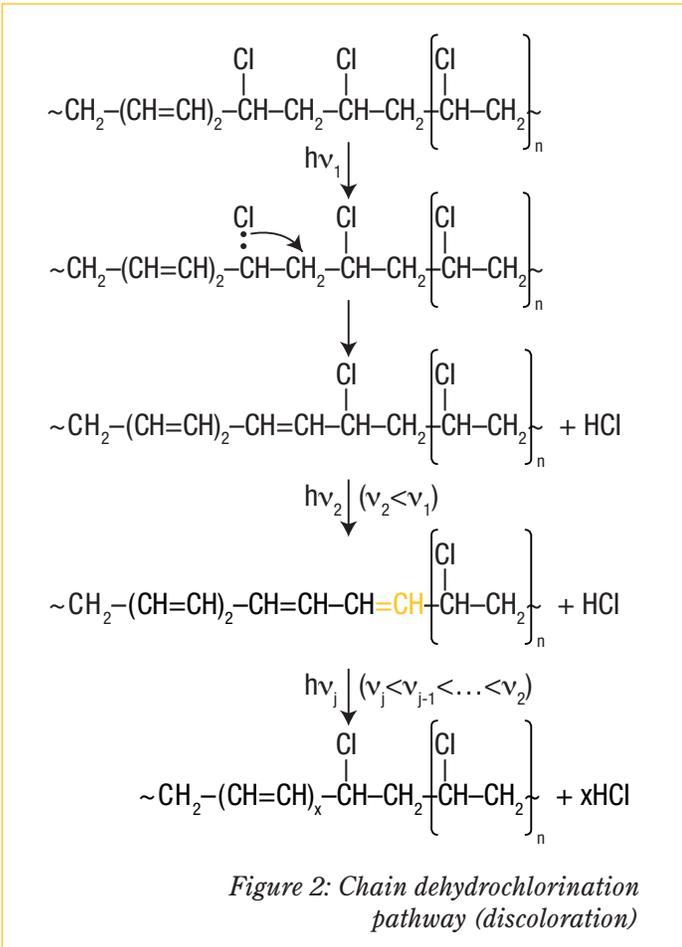
The second pathway proceeds from the random oxidation of the polyenic structures, i.e., the sequences of conjugated C-C double bonds, under the combined action of light and oxygen. In Figure 3, the example of the oxidation of a seven conjugated C-C double bonds chain, absorbing in the lowest part of the visible spectrum, leads to the formation of shorter unsaturated sequences, resulting in a bleaching.

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The third pathway is the oxidation of the normal structure of the matrix. A chlorine atom, produced from the first pathway can be ejected “out of its cage” and react on the nearby normal structure of a macromolecular chain, according to Figure 4. Among the two competitive ways leading to on one hand  $\alpha,\alpha'$ -dichloroketones and on the one hand to  $\beta$ -chloroacyl chloride and  $\beta$ -chloroacid, only the latter accounts for chain scission, i.e., mechanical damage.

It clearly appears that the first two processes only involve color change (discoloration and bleaching) as no chain scission occurs, while the third process induces chain scission through the production of uncolored oxidation products, i.e., affects the mechanical properties without inducing appearance change. Moreover, those three competitive processes are intricate and may not be accelerated with the same acceleration factor since the second and third processes are oxygen diffusion controlled while the first process is oxygen diffusion independent. Therefore, the geometry of the sample also has its importance. A 100  $\mu\text{m}$  thick transparent PVC film exposed outdoors does not develop any significant discoloration; yet it quickly yellows during an accelerated photo-aging test before a significant oxidation level is observed. It was shown that in accelerated conditions, a depletion of oxygen occurs in the core layers of the sample and prevents the complete oxidation of the longest polyenic sequences responsible for the discoloration. A 2 mm thick transparent PVC will discolor both outdoors and in accelerated photo-aging, as an oxygen starvation will inevitably occur in the core layers.

Therefore, to produce relevant results from accelerated tests, different procedures should be recommended according to the prevalent chemistry. Pigmented PVC, transparent thin rigid PVC, and transparent plasticized PVC (higher oxygen permeability than rigid PVC) will mostly undergo photooxidation, while thick transparent rigid PVC will quickly discolor before the development of a significant photooxidation. For formulations undergoing photooxidation, it is possible to observe the same result as in real conditions by reducing the thickness of the sample, and the test should be stopped whenever a discoloration occurs. The degradation extent will be estimated upon the measurement of photooxidation products. It is worth noting that transparent plasticized films should not be less than 200  $\mu\text{m}$  to prevent unrealistic loss of plasticizer. For pigmented formulations, in which the limiting factor is the penetration of light in both natural and accelerated weathering, thick samples can still be exposed, although thin samples are preferable for a number of reasons (analytical, early detection of physical degradation, homogeneity of the pigment dispersion).



## Controlled Acceleration of Photooxidation Reactions

The purpose of any accelerated test is to predict the loss of service properties occurring in a material under the effect of environment in a shorter period of time than its lifetime. The specific case of the PVC weathering illustrates the general importance of controlling the quality and intensity of parameters during such tests. From a mechanistic point of view, this means that the photooxidation mechanism characterizing the weathering in real conditions must be recognized during an accelerated test to assess its relevance to what is occurring in real conditions. [11, 16, 17, 18]

In order to be as close as possible to that goal, the physical and chemical stresses applied on the polymeric material during accelerated tests should meet the following requirements:

- Spatial uniformity of light exposure should be ensured by sample movement. If static, the steadiness of light intensity and spectral distribution should be checked in different positions on the surface of the exposed object. Considering that the usual geometry of light sources is cylindrical or spherical, it is difficult to ensure the uniformity of the incidental light over a large flat area.
- The incident light should not include radiations with wavelengths shorter than the daylight cut-on, i.e.,  $295 \pm 5$  nm. Upon the basis of fundamental photochemistry laws, such radiations may induce irrelevant photochemical reactions through the excitation of superior electronic excited states not reachable from daylight exposure. For instance, when aromatic polyurethanes are exposed to daylight, they are photooxidized into highly conjugated quinones, known as strong yellowing products. Irradiation of such aromatic polymers with wavelengths shorter than 295 nm has been shown to inhibit the discoloration that occurs in natural conditions. Some additives such as organic dyes and anti-UV are also prone to follow irrelevant reaction pathways, as their activity involves the excitation of their first electronic excited state for most of them. In both cases, excitation to superior electronic states might lead to unnatural photochemical processes like photo-scission or photo-bleaching. However, this condition is still ignored in some American Standards for Automobile Exteriors and Interiors, e.g., the recent SAE J2412.
- Contrarily to the situation with the simulation approach of polymers weathering, the spectral power distribution of the light source is not as important as it may seem for

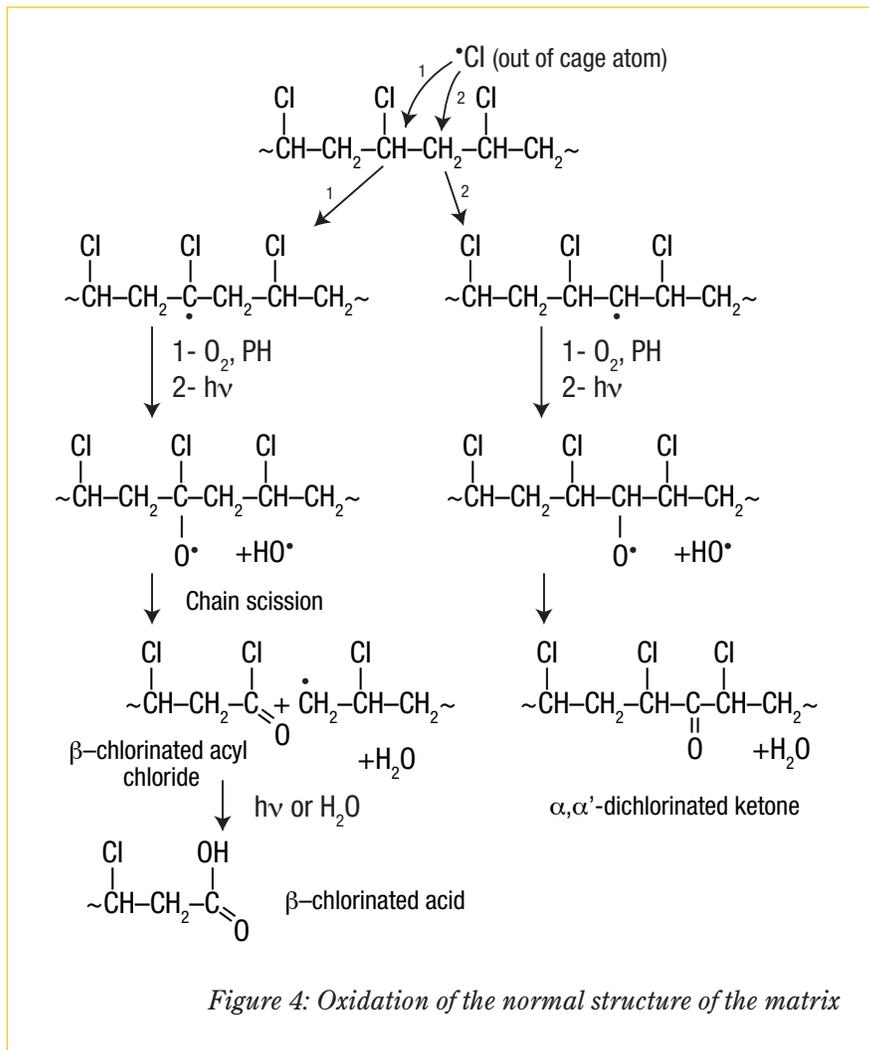


Figure 4: Oxidation of the normal structure of the matrix

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the purpose of accelerated tests. In most situations, providing a correct filtration is ensured, it is possible to use a source emitting a continuum (e.g., xenon lamp) or discrete lines (e.g., medium pressure mercury arc lamps) to induce identical photochemical processes. According to the fundamental concepts of photochemistry in the condensed phase, the activation of an excited electronic state in its superior excited vibrational levels is immediately followed by a vibrational relaxation prior to any photochemical process. Therefore, wavelength effects in the UV range, i.e., the modification of the observed chemistry through excitation at different wavelengths within the same absorption band of a compound, cannot exist in the solid state. Wavelength effects could only be observed if different absorbing compounds could be specifically excited by various wavelengths in a final formulation. Considering the broadness of the absorption bands of most organic or mineral compounds in the 300–450 nm range, that special case is seldom met. On the other hand, excitation in the visible range is only harmful in very particular cases (e.g., photo-oxygenation due to singlet oxygen in colored systems).

- d. The intensity of the incident light should be high enough to maintain photolysis and photooxidation as controlling degradation routes over thermooxidation. If the intensity of incident light is low (e.g., when simulating daylight), the temperature of the exposed surface should be kept low enough to prevent thermooxidation as the degradation pathway. On the other hand, the use of very intense light sources, like UV concentrator or high-powered pulsed laser concentrating up to 100 times the UV daylight, must be avoided, as the near simultaneous absorption of two photons may occur. This so-called biphotonic process is equivalent to the absorption of one photon having twice the energy of the incident photons. For instance, irradiating an object with a intense laser source emitting at 500 nm may provoke the same photochemical processes as those that would be activated by radiations of 250 nm. This effect is used in the biology field as an imaging microscopy technique.
- e. In weathering conditions, the photooxidation of the surface is rarely affected by oxygen depletion. Therefore, such an effect should not be limiting the rate of photooxidation in accelerated tests. For instance, during the accelerated aging of “transparent” polymers, which are not highly UV absorbing, if the permeability of the polymer to oxygen is not high enough, oxidation will occur only in the surface layers, whereas the core of the sample remains practically non-oxidized. In order to reduce this effect, the geometry of the exposed sample should be carefully designed (excessive thickness will lead to oxygen depletion, excessive thinness will lead to a fast loss of migrating additives). Therefore, the sample geometric design should be more conditioned by the exposure requirements than by the single degradation criterion used (e.g., the variation of mechanical properties).
- f. In environmental conditions, oxidation is activated both photochemically and thermally. The oxidation rate, i.e. the rate of formation of any final inert oxidized group on the polymeric chain, is given by the equation

$$Rate_{ox} = \sum_{\lambda_2}^{\lambda_1} [I_a(\lambda)]^\alpha e^{-\frac{E_a}{RT}}$$

where  $\lambda_1$  and  $\lambda_2$  are the limiting wavelengths of radiations inducing the elementary process,  $I_a$  the absorbed light intensity at wavelength  $\lambda$ ,  $E_a$  the apparent activation energy (when existing), and  $T$  the absolute temperature. The parameter  $\alpha$  is not temperature independent, and  $E_a$  is not independent on  $I_a$ . Consequently, the two types

of activation should be controlled simultaneously during accelerated artificial tests in order to ensure the reproducibility of results.

The temperature of the light-exposed surface should be determined within  $\pm 1$  °C during accelerated tests. For instance, it can be calculated from the above equation that hydroperoxides formed in polypropylene during an accelerated test will decompose 1.8 times and 1.35 times faster at, respectively, 64 and 62 °C than they do at 60 °C, using the activation energy for their decomposition found in the literature. Temperature control using an external reference black specimen is only indicative and relates to the temperature at the surface of this specimen only, as the temperature of an illuminated body is mostly determined by its color.

While the radiant energy and the spectral power distribution of most artificial light sources are usually well-controlled parameters, any discoloration during the exposure of a specimen will modify its light absorptivity, i.e. its surface temperature. Therefore, an accelerated test should be stopped before any excessive discoloration is achieved.

g. In environmental conditions, water may have various physical and chemical effects. Liquid water may lead to the erosion of oxidized layers, swelling of matrix, and extraction of additives soluble in water. Liquid or gaseous water may also induce the hydrolysis of oxidation intermediates or of final products. During artificial weathering or photo-aging in one single chamber, such perturbations cannot be induced simultaneously without considerable deviation from real conditions. Depending on the type of polymer, the nature of stabilizers (especially their solubility in water), and the climatic parameters, the relative importance of the different processes may be anticipated. The experimental design of a test should be based on the best understanding of the prevalent effect of water:

- If the predominant effect of water is presumed to be rinsing, water sprays are relevant.
- If the predominant effect of water is presumed to be swelling and extraction of stabilizers, sprinkling should be limited to prevent exaggerated swelling or extraction.
- If the predominant effect is presumed to be hydrolysis of final photooxidation products, post-immersion of the exposed samples in water is enough to lead to hydrolysis and to induce changes in optical properties.
- If water is able to react with intermediate degradation products, a combined effect of light, heat, oxygen, and water may be anticipated. However, in two common situations it is possible to evaluate the effect of water without having to supply it additionally:
  1. In the first case, we rely on water being formed internally. Hydroperoxides, which are thermally and photo-chemically unstable, are dissociated and in the process, hydroxyl radicals are formed. Such radicals are extremely reactive with any neighboring hydrogen atom, leading to water production. Water is thus supplied simultaneously with the hydroperoxides scission and in the same reaction zones as photooxidation intermediates, which are sometimes easily hydrolyzed, e.g., imides in polyamide (Figure 5).
  2. In the second case, the effect can be evaluated analytically from the kinetics of formation of an intermediate product (e.g., using appropriate spectrophotometric techniques) or from the accumulation of the compounds into which it is converted. In this case, application of water would be required only if the loss of a physical property, which depends on a complete hydrolysis of products, had to be evaluated.

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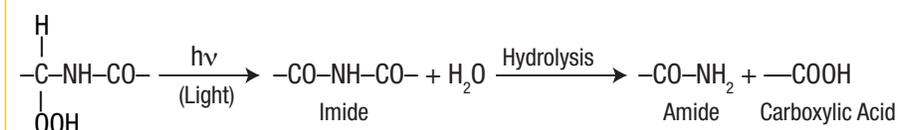


Figure 5: Hydrolysis of the imide group formed during the polyamide photooxidation

## Toward the Prediction of the Durability

- **Based on the evolution of the critical photoproduct concentration:**

When the photooxidation mechanism has been fully recognized, the controlling chemical damage is evaluated from the accumulation of the critical photoproduct. In accelerated conditions, the material lifetime is determined based on an established relation between the loss of a functional property of interest and the accumulation of the critical photoproduct. Prediction of the lifetime in natural conditions is then derived using the so-called acceleration factor which is defined as the ratio between the accumulation rate of the critical photoproduct in accelerated weathering and in weathering. [19] For obvious reasons, the accelerated test should be performed in a time span much shorter than the actual material lifetime in real conditions (e.g., during one summer for mildly stabilized formulations).

- **Based on the evolution of a functional property:**

If a substance's lifetime is defined on the basis of a mechanical property, which depends on the oxidation extent, prediction is difficult, though not impossible. [12] If the lifetime is based on the evolution of appearance properties, the prediction is far more complex if it is controlled by more than one simple dynamic chemical process, for the reasons explained earlier. If the visual properties are dominated by the loss of gloss or micro-cracking, then oxidation is the dominating mechanism and lifetime prediction is possible. [20] However, if the visual aspect is a consequence of several simultaneous processes, such as oxidation, photolysis, formation and bleaching of yellowing products, formation and photo-oxidation of fluorescent compounds, decomposition of pigments or dyes, then lifetime prediction is only possible if one of these phenomena appears as dominant.

## Conclusion

Although it is widely recognized that more efforts should be put into understanding the underlying chemical processes occurring at the molecular level, which are responsible for the physical evolution of a polymeric object, durability studies in the field of material testing still heavily rely on correlating the evolution of physical properties between natural weathering and accelerated weathering, like color or gloss measurement.

The photochemical degradation of macromolecules in general appears to be fairly complex. Variations of physical properties and of chemical composition can easily be observed during photo-degradation in real life conditions. However, since long periods of time are involved, the variations in environmental parameters (temperature, humidity, light intensity) are not accurately known, although they may be monitored throughout the experiment.

At the laboratory level, each accelerated weathering instrument has intrinsic characteristics depending on the light source used and the type of temperature and humidity control. The relevance of accelerated laboratory experiments to service life conditions cannot be easily and reliably assessed from the variations of functional properties like mechanical or optical changes, since the same variation can have several different origins. Reliability

is gained when relevance is assessed by a more detailed survey of the various processes occurring at the molecular level. ■

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## Atlas Offers Qualified Network of European Testing Laboratories

Do you need to perform light- and weatherfastness testing on your materials but don't have the appropriate testing equipment on hand? Atlas offers a qualified network of test laboratories throughout Europe that can meet your testing needs.

Atlas labs offer 54 state-of-the-art weathering testing instruments in England, France, and Germany. Whether you need xenon arc testing, carbon arc testing (Sunshine or Enclosed Carbon Arc), Solar Climatic testing, or a testing to meet the Renault guidelines, Atlas offers the right instrument in a convenient location.

### > *Laboratory Germany*

The largest Atlas laboratory with 24 testing instruments is located in Duisburg, in the industrial heart of Germany. Since 2002, the laboratory has been certified for accelerated light- and weatherfastness testing in accordance with DIN EN ISO/IEC 17025:2000. The accreditation certifies that all applied products and methods as well as the measuring and testing results are objective and transparent.

### > *Laboratory UK*

Our laboratory in Bicester, UK, moved to new facilities in 2005 and is now situated seven miles northeast of Oxford. The new laboratory offers Atlas' Ci Series and Xenotest® xenon arc weathering instruments as well as SUNTEST table-top units. The laboratory also houses a number of enclosed/sunshine carbon arc instruments making it the most comprehensive carbon arc testing facility in Europe. The enhanced testing capabilities will help Atlas MTT Ltd. to gain ISO 17025 accreditation in addition to BS EN ISO 9001:2000 accreditation.

### > *Laboratory France*

Our third European laboratory is located in Moussy le Neuf, north of Paris. Since 2004, the laboratory has been certified for accelerated light- and weatherfastness testing in accordance with DIN EN ISO/IEC 17025:2000. The laboratory in France is a certified Renault laboratory that allows us to test materials according to Renault guidelines. All the results will be accepted by Renault as well as by their suppliers.

All three climate-controlled laboratories are able to test materials such as plastics, rubber, sealants, paints, coating materials, interior or exterior automobile components, textiles, printer inks, and much more. Additional services relate to the analysis and evaluation of exposed samples according to visual assessment, color and gloss measurement, chalking, and more. Further expanded services include the possibility to provide in-house seminars at our laboratories such as the Fundamentals of Weathering and instrument-specific workshops.

Whether you would like your materials to be tested in Germany, the UK, or France, one thing is guaranteed: You will always give your order to a laboratory with decades of proven expertise in light- and weatherfastness testing. In Germany and France, we have been accredited by the German accreditation council, and in the UK, an independent accreditation will follow in spring 2006.

Using an Atlas lab guarantees that your tests will be conducted in an efficient manner, correctly, and at an affordable price. Test us!

Are you interested in visiting one of the laboratories or do you need a quote?

Please do not hesitate to contact us:

**Laboratory Germany**, Agnete Steegers, Tel. +49 2065-76490 or Siegfried Roessner, Tel. +49 2065-76490; **Laboratory UK**, Tracy Tompkins, Tel. +44 01869-365440; **Laboratory France**, Isabelle Maret, Tel. +33 1 60 54 94 00 ■

## New High-Efficiency Lamp Cooling System Added to Ci Weather-Ometers

Atlas has introduced a new lamp cooling system for our Ci Series Weather-Ometers. An upgrade to the CS-6 lamp cooling system, the new CS-7 offers substantial water savings.

The new, high-efficiency water-cooled CS-7 model will soon come standard in all Ci instruments. The CS-7 replaces the double-coil system used in the CS-6 unit with a high-efficiency heat exchanger that will reduce the amount of tap water used by 50%, depending on test methods, model selected, and ambient conditions.

Ci instruments (Ci3000, Ci4000, and Ci5000) can be retrofitted with the CS-7. For more information about the new lamp cooling system, please contact a sales representative at +1-773-327-4520 or [info@atlas-mts.com](mailto:info@atlas-mts.com). Visit the Atlas website at [www.atlas-mts.com](http://www.atlas-mts.com). ■



### Harold Hilton Heads Up New ASTM Corrosion Subcommittee

ASTM B117 standard practice for operating salt spray (fog) apparatus is one of the most utilized ASTM standards. Since its inception, it has contained appendix (non-mandatory) information indicating general equipment types utilized to perform the tests. It is the desire of ASTM committee G.01.05 Laboratory Corrosion Tests to compose a new ASTM standard for the salt fog test apparatus separate from the test procedure contained in the B117 specification. The effort to produce this new standard would be under the jurisdiction of ASTM subcommittee G.01.05.03 Cabinet Corrosion Tests.

**Harold Hilton**, Product Specialist, Atlas Material Testing Technology, Chicago, has accepted the opportunity to lead this effort. He will be working with ASTM members and experts in the field of lab corrosion testing to accomplish this task.

If you have any questions or recommendations, you may contact Harold at [hhilton@atlas-mts.com](mailto:hhilton@atlas-mts.com).



## AtlasSpeaks

# 2006

### **Gesellschaft für Umweltsimulation Annual Meeting**

March 22–24  
Pfinztal, Germany

**Dr. Artur Schönlein** will present “Shorter Test Times for Colour Fastness and Automotive Lightfastness.”

### **Forced Degradation (Large Molecules)**

March 27–29  
San Francisco, California, USA

**Al Zielnik** will present “Strategies and Technologies for PhotoStability Stress Testing.”

### **Spectrum of Coatings**

April 19  
Louisville, Kentucky, USA

**Matt McGreer** will present “Significance of Standard Reference Materials for Weathering Testing Instruments.”

### **International Congress of Imaging Science**

May 7–11  
Rochester, New York, USA

**George Coonley** and **Matt McGreer** will present “Determination and Validation of the Spectral Power Distribution of Artificial Weathering (Lightfastness) Instruments.”

*For the latest on Atlas shows and presentations, visit [www.atlas-mts.com](http://www.atlas-mts.com).*

### **ESTECH**

May 10  
Phoenix, Arizona, USA

**George Coonley** will present “Methods for Determining Solar Radiation Levels Based on End Use Locations and Conditions Using the CESORA Solar Radiation Modeling System.”

**Al Zielnik** will present “Terrestrial Climatic/Solar Simulation for Material & Product Durability Assessment.”

### **ATCAE**

May 11–12  
Ile des Embiez, France

**Dr. Olivier Haillant** will present “Experimental Techniques in Studies of Photo-Stability.”

**Kelly Hardcastle** will present “A Characterization of the Relationship Between Light Intensity and Degradation Rate for Weathering Durability.”

**Burkhard Severon** is presenting “Correlation of Outdoor Weathering vs. Accelerated Weathering Including the Calculation of Effective Solar Radiation.”

**Richard Slomko** will present a paper “Guidelines for Conducting Outdoor Exposure Testing.”

### **Federation of Scandinavian Paint and Varnish Technologies**

(SLF) 18th Conference 2006  
October 8–10  
Elsinore, Denmark

**Dirk Oefner** will present “Basics of Accelerated Aging of Polymers, AWT International Standards for Coatings and Testing of Polymers & Coatings.”



## **NPE International Plastics Showcase**

Chicago, Illinois (USA)  
June 19–23, 2006  
Booth 6133

From June 19–23, NPE 2006: The International Plastics Showcase will be held at McCormick Place in Chicago, Illinois (USA). The event is the largest trade event dedicated to the plastics industry. Atlas Material Testing Technology LLC will exhibit in Booth 6133, located in the North Hall of McCormick Place. We will showcase three of our xenon exposure instruments, the Ci4000 Weather-Ometer®, the SUNTEST XXL+, and SUNTEST XLS+. Atlas provides an extensive range of weathering and lightfastness testing instruments for the plastics industry. Visit us at NPE to find out how we can help you meet plastics industry testing standards.

## Atlas Commitment to Growth

### Second ATCAE Set for May in France

On May 11–12, 2006, Atlas Material Testing Technology will hold the second ATCAE (Atlas Technical Conference for Accelerated Ageing and Evaluation) on Ile des Embiez near our outdoor site in Sanary-sur-Mer, France. ATCAE 2006 will focus on natural outdoor weathering and laboratory weathering, as well as the correlation between these two methods.

The event will primarily address the plastics, paint, and automotive industries but will be relevant for all related industry branches such as the glass and rubber industries.

Presentations will be given by noted speakers from France, Germany, The Netherlands, and Switzerland, as well as outdoor weathering experts from Atlas.

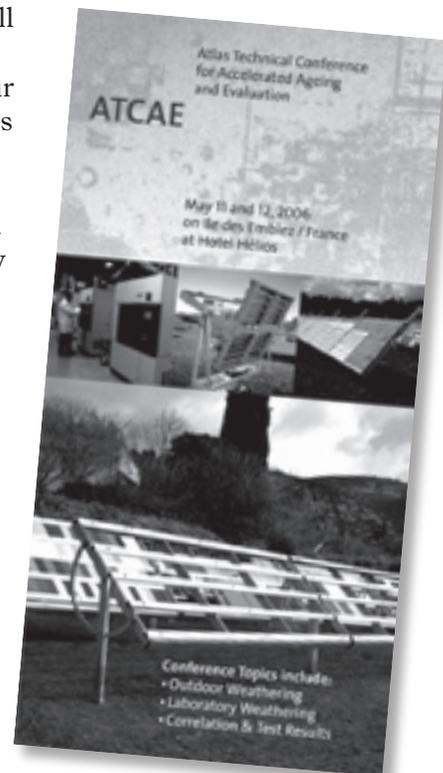
A total of 14 presentations have been scheduled, including:

- Accelerated weathering device for service life prediction for organic coatings
- Artificial weathering and outdoor exposure of polyester coatings
- Influencing variables of weathering results on coatings for plastic components in the automotive industry
- Simulation of natural weathering

The conference will provide insights into the newest results and the latest weathering technologies. It will also offer the chance to get to know the climatic and the environmental conditions of the Atlas outdoor weathering site in Sanary-sur-Mer.

Located in the south of France on the Mediterranean Sea, the Sanary-sur-Mer site is becoming increasingly important for European testing and is evolving into a European reference climate. It is one of 20 outdoor sites around the world offered by Atlas Weathering Services Group. Since 1930, Atlas has maintained global outdoor weathering sites, not only in the most important reference climates of the world, but also in different climates for special applications.

The conference is open to all. If interested, please contact Bruno Bentjerodt, Client Education, +49-6051-707-245 or visit our website: [www.atlas-mts.com](http://www.atlas-mts.com). ■



#### Information:

Atlas Material Testing Technology GmbH  
Marketing Services  
Vogelsbergstrasse 22  
63589 Linsengericht-Altenhaßlau

**Tel.:** +49-6051-707-160

**Fax:** +49-6051-707-161

**E-mail:** [clienteducation@atlasmtt.de](mailto:clienteducation@atlasmtt.de)

**Web:** [www.atlas-mts.com](http://www.atlas-mts.com)



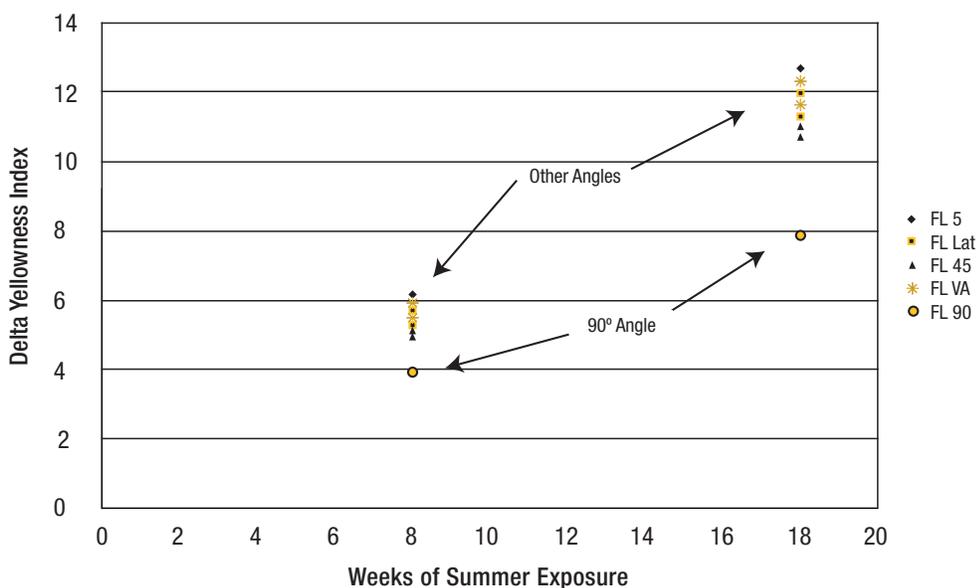
## Weathering Experimenter's Toolbox: 90° vs. Other Angles

By Henry K. Hardcastle, III

In early weathering research, paint systems were applied to vertical walls facing south and exposed for performance evaluations. Soon after, it was noted that changing the angle from 90° to 45° South produced faster degradations. This increase in degradation rate was significant and important. Since that development, researchers have proposed a number of other exposure angles often described as optimal for faster degradation rates. A variety of explanations includes ratio of direct to diffuse component of sunlight, cooling of night sky, and condensation on surfaces. Horizontal, at latitude and variable angle have all been recommended over the 45° exposure primarily for faster degradation rates. For some materials, changing standard exposures from 45° to these other angles can result in important increases in degradation rates. However, for others, changing from 90° to 45° results in a quantum leap in degradation rates, but changing from 45° to other “optimal” angles offers only marginal increases in degradation rates.

For example, identical pieces of polystyrene reference material were randomly selected from a single lot. Two pieces were placed on different angles of exposure in Florida simultaneously. The degradation in yellowness index was measured after eight and 18 weeks exposure from May to August. The following results were obtained.

Effect of Exposure Angle on Polystyrene Chips in Florida



The differences between the 90° and other angles of exposure were significant and important. The differences between other angles may have been significant but were much less important. Visual analysis indicated the difference between 90° and other angles was important—but not important within angles other than 90°. Changing from 90° to other angles of exposure may represent an important tool for weathering researchers, whereas changing between other angles may offer less acceleration, depending on the material and environment. ■

## Atlas Weathering Services Group

# Atlas Provides More Value for Natural, Accelerated and Laboratory Weathering Testing

### *Value-Added Services Offer Fast and Convenient Assistance*

Atlas Weathering Services Group (AWSG) is pleased to announce a suite of value-added services available with every test program—at no additional cost.

“We now offer a suite of 10 powerful value-added services that provides our customers web access to information and data to meet their testing needs and additional services to ensure high quality and effective test programs,” says Richard Slomko, General Manager AWSG-USA. “With more information at their fingertips, our customers are able to achieve their ultimate goals—a quality product, a competitive edge, and a faster time to market.”

The new value-added suite of services offers an unparalleled level of service and support only offered to AWSG customers. The program delivers vital desktop access to real-time information as well as extraordinary levels of expert guidance and assistance.



From the comfort of your office, you have access to:

- **Live test tracking** that allows you to view evaluation services and receive up-to-date radiation values on Atlas' secure, password-protected web-site
- **Request for quotations** via Atlas' website with prompt quotes via e-mail
- A complementary **digital photo** of your specimens on the exposure rack with an acknowledgement letter
- **Evaluation reports** in Excel spreadsheets and all other reports sent to your e-mail as PDF files
- **Past evaluation reports** through a secure area on Atlas's website
- Automatic **e-mail tracking** information on return tests sent via Federal Express or UPS

For expert advice and information as well as additional convenience, the services also include:

- **Design of experiment assistance** from some of the foremost experts in weathering test design
- Expertise in **international standards** as well as over 20 weathering test sites in a variety of climates around the world to address specific markets and regions
- **Bar coding** of each specimen for continuous tracking while they are on exposure

For more information about our value-added services, please contact one of our client service representatives +1-800-255-3738 or [info@atlas-mts.com](mailto:info@atlas-mts.com). Visit the Atlas website at [www.atlas-mts.com](http://www.atlas-mts.com). ■

## Atlas to Expand Florida Testing Capabilities

### *New Florida Facility and Expansion Provides Pristine Testing Environment!*

Atlas Weathering Services Group is significantly expanding its services by creating the world's largest and most advanced global benchmark weathering testing facility in Miami, Florida. The expansion is made possible by the purchase of 18 acres of pristine land in close proximity to our current South Florida Test Service (SFTS) Everglades site, located 56 km (35 miles) southwest of Miami International Airport—a site widely acknowledged as the most unspoiled and protected exposure site in south Florida. By combining the existing SFTS Everglades site with the additional acreage, AWSG can now offer a single, consolidated weathering exposure center in Miami, bringing together the unique resources of both Florida facilities.

“Our customers expect industry leadership from Atlas and this new exposure site will further secure our position as the leaders in weathering,” says Jack Martin, President of AWSG. “As development has encroached on our SFTS site at Okeechobee Road and we have continued to operate two separate test sites in Miami, we have now realized our goal to consolidate our sites in the most pristine testing environment in south Florida. The expanded facilities of our Everglades site will serve as the AWSG worldwide headquarters, combining the world's most sophisticated accelerated weathering laboratory, outdoor weathering services, and sample evaluation facilities.”

AWSG is developing a timeline for the expansion of the Everglades site facilities, the preparation of our new exposure field and the ultimate closure of the SFTS test site on Okeechobee Road. The timetable will be communicated with clients as soon as it is completed. Currently, some test exposures are being moved to the Everglades site as AWSG begins the transition to a single, consolidated test site. AWSG will continue to keep you informed on the progress of the expansion, share important milestones, and most importantly solicit your input on your testing needs.

For additional information, please contact Richard Slomko, General Manager, AWSG USA, at +1-305-824-3900 or [rslomko@atlas-mts.com](mailto:rslomko@atlas-mts.com). ■

### **Surfex, Manchester, United Kingdom**

June 21–22, 2006  
Booth 151

The largest and most comprehensive UK exhibition for the surface coatings, printing inks, adhesives, corrosion, and construction chemicals industries, the **SURFEX**, will be held at the Manchester GMex International Centre June 21–22. Atlas will display our new SUNTEST XXL. With its 3000 cm<sup>2</sup> specimen tray, the XXL is ideal for high volume testing and testing of large components and three dimensional parts.

## AWSG Adds New Site to Worldwide Exposure Network

AWSG is pleased to announce the addition of a new Worldwide Exposure Network (WEN) site in Deerwood, Minnesota, USA. Extreme cold temperatures that characterize this site during the winter months will provide valuable test data for some plastic and other materials that may fail in extreme cold end-use conditions.

The Minnesota exposure site is categorized as a northern cold climate. The site has numerous winter freeze days and freeze/thaw cycles in spring and fall, as well as temperate summers. The site is located at 46° 47' North Latitude and 93° 9' West Longitude. The annual mean temperature is 5.3 °C and the mean relative humidity is 70%. Annual precipitation is approximately 700 mm and the site averages approximately 5,000 MJ/m<sup>2</sup> of total radiation per year.

The growing AWSG WEN has over 20 sites around the world to meet our clients' needs. If you are interested in exposing specimens at any of our sites please contact your client service representative at +1-800-255-3738 or visit our website at [www.atlas-mts.com](http://www.atlas-mts.com). ■



Atlas' new Deerwood, Minnesota site offers northern cold climate testing.

## Atlas Client Education 2006

Atlas Client Education helps clients learn to design durability test programs to understand how weathering affects materials. Our education and training solutions will help you and your staff effectively master the skills and knowledge needed to develop long-lived products in shorted development cycles. Our programs are designed for all levels to ensure that everyone develops the skills required to understand the fundamentals of weathering and how to operate our instruments. For the latest schedules and locations, check the Atlas website [www.atlas-mts.com](http://www.atlas-mts.com) or e-mail [info@atlas-mts.com](mailto:info@atlas-mts.com).

### ATCAE

*(Atlas Technical Conference for Accelerated Ageing and Evaluation)*

May 11–12  
Ile des Embiez (near Sanary-sur-Mer), France

### SUNTEST Workshop

*Linsengericht, Germany*

March 24  
October 20

### XENOTEST® Workshop

*Linsengericht, Germany*

March 21–22  
October 17–18

### Fundamentals of Weathering I

March 21  
Lochem, The Netherlands

March 30  
Paris, France  
April 6  
Miami, FL, USA

April 11  
Moscow, Russia

May 30  
Oensingen, Switzerland  
September 6  
Kassel, Germany

October 12  
Miami, FL, USA

### Fundamentals of Weathering II

March 28  
Lochem, The Netherlands

March 31  
Paris, France  
April 7  
Miami, FL, USA

May 31  
Oensingen, Switzerland

September 7  
Kassel, Germany  
October 13  
Miami, FL, USA

### Weather-Ometer® Workshops

*Miami, Florida, USA*

April 2  
Ci4000/Ci5000

June 4–5  
Ci35/Ci65

October 9  
Ci4000/Ci5000

October 10–11  
Ci35/Ci65

October 12  
Advanced Ci35/Ci65

*Duisburg, Germany*

October 24–25  
All Ci Instruments



For more information on courses in Europe, contact Atlas MTT GmbH, attention Bruno Bentjerodt, +49-6051-707-245 or [clienteducation@atlasmtt.de](mailto:clienteducation@atlasmtt.de).

For more information on courses in North America, contact Kerry Quilter at +1-773-327-4520 or [kquilter@atlas-mts.com](mailto:kquilter@atlas-mts.com).

Or visit our website at [www.atlas-mts.com](http://www.atlas-mts.com).

Visit us  
at SAE  
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Detroit, MI  
Booth 627

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## Atlas Material Testing Solutions

### **Atlas Material Testing Technology LLC**

4114 North Ravenswood Avenue  
Chicago, Illinois 60613, USA  
Phone: +1-773-327-4520  
Fax: +1-773-327-5787

### **Atlas Material Testing Technology GmbH**

Vogelsbergstrasse 22  
D-63589 Linsengericht/Altenhaßlau  
Germany  
Phone: +49-6051-707-140  
Fax: +49-6051-707-149

### **K.H. Steuernagel Lichttechnik GmbH**

Gerauer Straße 56a  
64546 Mörfelden-Walldorf, Germany  
Phone: +49-6105-91286  
Fax: +49-6105-912880

### **Atlas Weathering Services Group South Florida Test Service**

17301 Okeechobee Road  
Miami, Florida 33018, USA  
Phone: +1-305-824-3900  
Fax: +1-305-362-6276

### **DSET Laboratories**

45601 North 47th Avenue  
Phoenix, Arizona 85087, USA  
Phone: +1-623-465-7356  
Fax: +1-623-465-9409  
Toll Free: 1-800-255-3738

### **KHS US Office**

4114 North Ravenswood Avenue  
Chicago, Illinois 60613, USA  
Phone: +1-773-327-4520  
Fax: +1-773-327-5787

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ATLAS MATERIAL TESTING TECHNOLOGY LLC  
4114 North Ravenswood Avenue  
Chicago, Illinois 60613, USA