ATLAS
MATERIAL TESTING SOLUTIONS

SunSpots

Material Testing Product and Technology News

Volume 33
Issue 69

Spring 2003

Light: Its Relevance, Characterization, and Measurement in Weathering Tests

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Introduction

Light is undoubtedly one of nature's most fascinating forces. It determines our weather and sustains all forms of life. Because of its abundance, mankind has tended to take light for granted. All of us intuitively have a sense of what light is, yet only few have an appreciation of the scope of its complexities. Through the ages, preeminent scientists have spent much time studying light. Albert Einstein, for example, was so intrigued by the subject that he was inspired to declare, "I want to reflect on light for the rest of my life."

Einstein's "reflection" and the important work done by many of his predecessors—Isaac Newton chief among them—established the basis of the fundamentals of light science. The modern world has continued to develop the light technology that has changed our world with applications that even the great Newton could not have foreseen. Today, electro-optics, the marriage of light and electronics, is perhaps the most powerful technology. It pervades our lives in the areas of entertainment, medicine, communications, and warfare, to name a few.

Light has a destructive side as well. Increased rates of skin cancer are directly attributable to the ever-popular habit of suntanning—over-exposure of the skin to sunlight. It is also well known that all organic materials are degraded under exposure to light, especially in conjunction with other weather factors. Its strong influence in materials degradation makes light the core of weather durability tests.

The intent of this paper is to impart to those specifically involved in weatherability tests, a rudimentary understanding of light and an overview of the means typically used to characterize and manipulate it for the purposes of such tests. This paper will not attempt to instruct comprehensively on the subject of light—indeed, that would be impossible

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Atlas' EverSummer program uses test sites in Miami, Florida, USA, and Townsville, Australia. *Page 16*

In This Issue

AtlasTest Instruments Group

Photo Industry Turns to Atlas' Pioneering Lux Method

The photographic industry has changed dramatically over the past 10 years. Taking film to a photo lab is no longer necessary when a photographer has access to a computer and an ink jet printer. Consequently, the market for ink jet printers has boomed over the past few years, and now more people than ever are printing their own photos. Demand has also grown for high-quality, long-lasting inks and papers. But with the abundance of these products on the market, consumers are looking for a way to rate and compare them for various durability and stability characteristics. For example, do I use OEM products or can I use aftermarket?

These are the issues being addressed by the ISO WG-5 Task Group 3 (TG3), comprised of ink, paper, and printer companies from around the globe: Canon, Creative Memories, Epson, Fujifilm, Hewlett Packard, Ilford, Kodak, Lexmark, and Polaroid, to name a few. With Atlas' help, TG3 is working to develop an appropriate test method. The new method will include various testing conditions based on measurements taken from actual end-use environments such as homes, offices, and storefronts.

Lux measurements from the Atlas Ci3000 (above) and Ci4000 (below) will help the photo products industry better respond to standards and the demands of consumers.

Like other applications, light is a major concern and factor in the degradation of a print. For years now, the photographic industry has been taking on-site light measurements with hand-held meters recording in units of lux. The new test method will specify a lux value for both "indirect indoor" and "behind window glass" test conditions.

Atlas now offers both measurement and control of lux in our latest generation Weather-Ometer®. As a TG3 member, Atlas has worked closely with the group to meet the light stability testing needs of the inkjet products industry. In fact, this feature has already been successfully installed at several companies, including Wilhelm Imaging Research, Inc., our own South Florida Test Service, and Creative Memories.

Creative Memories offers quality photo-safe products for photo preservation and journaling. The company owns a Ci3000 Weather-Ometer and has recently installed the lux control and monitoring feature. Dr. Mark Mizen, Director of Technology at Creative Memories, had this to say about his recent upgrade:

"The new lux monitoring and control feature installed in my Weather-Ometer is exactly what this industry has been waiting for. Atlas has listened to its customers and is now the only company offering test instruments that control light in a manner that directly corresponds to real-world measurements. With a new ISO standard for image stability almost complete, our Ci3000 is ready to meet the lux requirement, as well as other test conditions for light stability."

For more information on how Atlas can measure lux using a Ci Series Weather-Ometer, please contact your local Atlas Sales Representative or email info@atlas-mts.com. ■

Color Printouts–A Closer Look

Fresh from the printer or photo lab, pictures look great, but colors often fade after only a short time. *PC Welt,* a German computer magazine, has examined this phenomenon by studying how the ink and type of paper used affect the light stability of inkjet prints.

Using Atlas' SUNTEST CPS+ tabletop unit, prints from four different inkjet printers—each produced on the recommended type of paper—were subjected to artificial aging under light. A six-month period of direct exposure to sunlight behind window glass was simulated by using the integrated xenon lamp. The accelerated testing compressed six months into a duration of 17 days. Colorimetric measurements were made before and after the exposure test.

Atlas' SUNTEST CPS+ tabletop unit puts photo paper to the test.

The measurements produced a few interesting results. In general, pigmented inks are more stable than non-pigmented inks because the former contain solids that are more light stable to carry the colors. However, poor light stability of non-pigmented inks is somewhat compensated for by more detailed color reproduction where the color molecules are entirely dissolved in liquid.

It is not only the ink that is important for light stability, but the type of paper used as well. Not all photo papers are created equal. More expensive photo paper can pay for itself by providing more brilliant colors when compared to inkjet paper. Its multiple layers serve to protect color molecules more effectively against light. Photo papers may come with polymer or micro-porous coatings. Polymer-coated paper, which is only suitable for non-pigmented ink, is generally more colorfast because it bonds the ink to its interior, building up a protective layer against the effects of light. Micro-porous coated paper can be employed for both pigmented and non-pigmented inks, but the lack of an effective protective layer means it is less resistant to the influence of sunlight.

Interestingly, samples from photo labs exposed and evaluated in the same process actually aged more rapidly than images produced on an inkjet printer!

Source: *PC Welt,* 4/2003

AtlasSpeaks

2003

Textile Health Ecology
May 14–15
Zilina, Slovakia

Dirk Oefner, Atlas Material Testing Technology GmbH, and Jozef Maco, Comedis Spol. S.R.O., will make a presentation regarding lighfastness, colorfastness, pilling, and flammability and how these relate to field of textiles.

XXIX Colouristic Symposium
May 26–28
Eger, Hungary

Dirk Oefner, along with G. Haasz and Zoltan Sandor, Realinfo K.F.T., will present a paper titled "UV2000 for Testing of Paints and Coatings."

EUROCORR 2003
September 28–October 2
Budapest, Hungary

Dirk Oefner and Cees Van Teijlingen, Atlas Material Testing Technology GmbH, will make a presentation on VIEEW and how it relates to corrosion analysis.

FSCT ICE 2003
November 12–14
Philadelphia, Pennsylvania, USA

Kelly Hardcastle, Atlas Weathering Services Group, will present a paper titled "Variables, Methods, and Philosophies Considered in Coatings Durability."

*For the latest on Atlas shows and presentations, visit **www.atlas-mts.com.***

AtlasShows

2003

Quality Expo
April 15–17
Donald E. Stevens Convention Center
Rosemont, Illinois, USA
Booth #13116

International Hosiery Expo
May 4–6
Charlotte, North Carolina, USA
Booth #1003

PLAST 2003
May 6–10
Milan, Italy

Apparel Sourcing 2003
May 7–9
Guatemala City, Guatemala

TEST
May 13–15
Nürnberg, Germany
Booth #7/7A480
(K.H. Steuernagel exhibiting)

ACHEMA 2003
May 19–24
Frankfurt, Germany
Hall 6.1, Booth #C23

Sink or Swim 2003
May 21
Cleveland, Ohio, USA

NPE 2003
June 23–27
McCormick Place
Chicago, Illinois, USA
Booth #4333

Latin American Coatings Show
July 16–17
Mexico City, Mexico

CHEMISTRY
September 8–10
Moscow, Russia

PDA
September 8–10
Washington, D.C., USA

AATCC
September 9–12
Greenville, South Carolina, USA

EUROCORR 2003
September 28–October 2
Budapest, Hungary

IFAI 2003
October 1–3
Las Vegas, Nevada, USA

PACK EXPO
October 13–15
Las Vegas, Nevada, USA

FAKUMA
October 14–18
Friedrichshafen, Germany

ITMA 2003
October 22–29
NEC
Birmingham, England
Hall 5, Booth #T5-19D

Test Expo 2003 North America
October 29–31
Novi Convention Center
Novi, Michigan, USA
Booth #5016

FSCT ICE 2003
November 12–14
Philadelphia, Pennsylvania, USA

RICH-MAC
November 25–28
Milan, Italy

Light, from page 1

in this context, and there are many excellent texts and courses available for that purpose.

What is Light?

Light is a pure form of energy. As we think of it, or perhaps more correctly, see it, light is only a small portion of the electromagnetic spectrum (Figure 1). The somewhat more expansive optical spectrum includes the invisible infrared (IR) and ultraviolet (UV), which were discovered sometime after Newton's initial experiments that demonstrated that white light can be separated into light of several colors. Like many other important scientific breakthroughs, Newton's first indication that white light was a composition of all other colors was by chance.

Like many before him, Newton noticed that the sunlight streaming through his window cast an image of many colors on his floor. His piqued curiosity led to experiments that eventually bore out his suspicions that white light is indeed comprised of all colors of light (Figure 2). The array of colored lights derived from white light came to be called the "spectrum." Later studies of the spectrum indicated that a source of energy beyond the red light caused an elevation in temperature. Upon finding this unexpected energy source (IR), investigation of the portion beyond the violet at the other end of the visible spectrum ultimately led to the discovery of a high energy band later named the ultraviolet.

Beginning with Newton's simple experiments, the study of light developed into a full-fledged science. The question of how light traveled was pondered for centuries. It was theorized and ultimately shown that the propagation of light can be explained both by wave form and particle theory. This seemingly contradictory phenomenon known as the "dual nature of light" confounded some of the great minds of science. Albert Einstein, who contemplated the problem in the early part of the last century, attempted to reconcile the dilemma by introducing another complicated concept. He theorized that light travels in discrete packets referred to as photons. A full explanation of these theories is beyond the scope of this paper. Therefore, it is practical to accept Thomas Brill's approach. He wrote, "...it is now generally conceded that one must accept the inadequacy of any simple model in explaining something so basic as light. The modern theory of light can only be stated in mathematical form…rather than trying to go further in 'explaining' light it is more useful to concentrate on its practical properties." [1]

In 1900 Max Planck established that the energy (E) of

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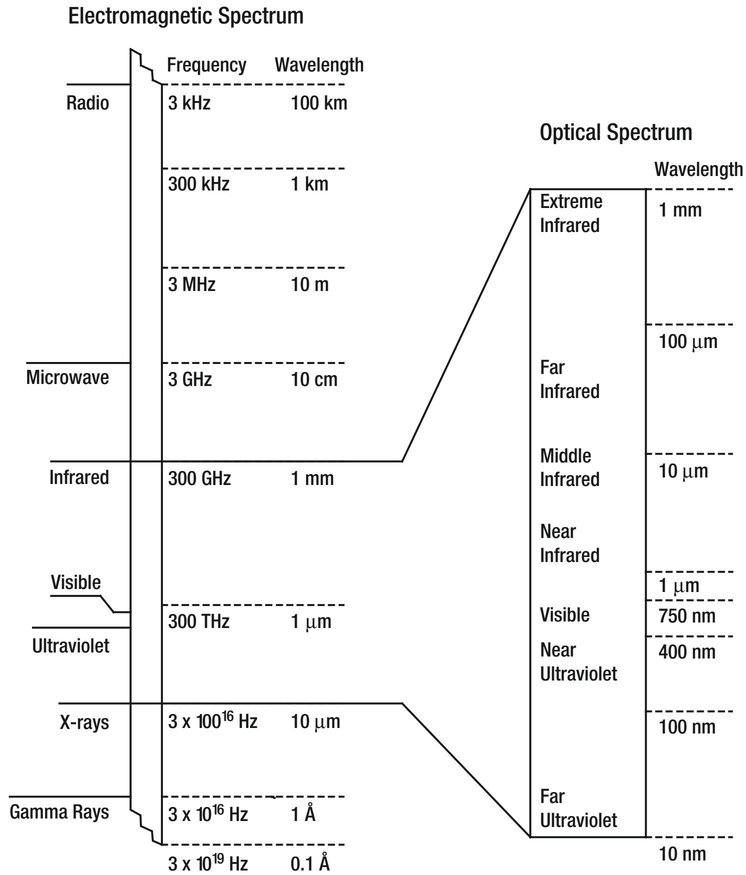

Figure 1: Electromagnetic spectrum

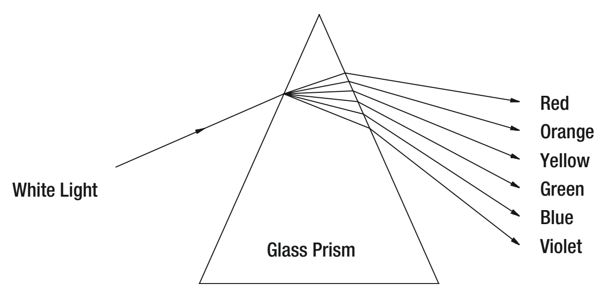

Figure 2: Dispersion of white light by a prism

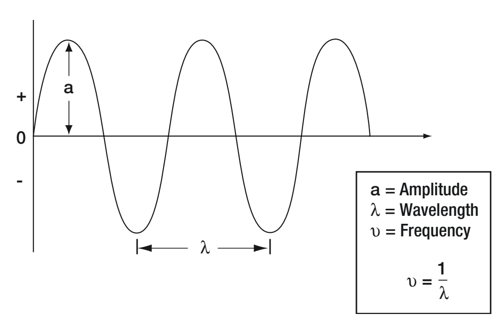

Figure 3: Properties of a wave

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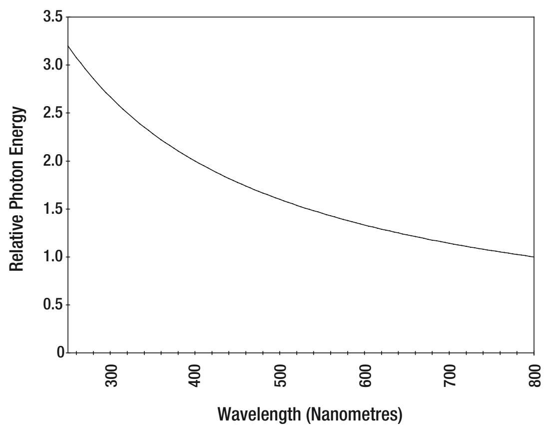

Figure 4: Relative photon energy as a function of wavelength

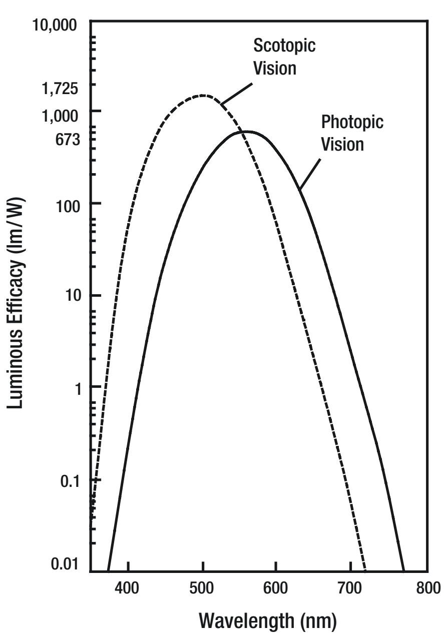

Figure 5: Response curve of the human eye

emitted radiation is proportional to its frequency (υ) according to the following equation, where h is a constant:

$$E = h\upsilon \qquad \text{[Equation 1]}$$

If c is the velocity of light in a vacuum, Planck's equation may be expressed in another useful form:

$$E = hc/\lambda \qquad \text{[Equation 2]}$$

since frequency (υ) is inversely proportional to wavelength (λ). Therefore, different energies can be expressed in terms of different wavelengths. The relationship shown in Equation 2 indicates that greater energies are associated with (smaller) λ's or shorter wavelengths. Figure 3 (previous page) shows the relationship between frequency (υ) and wavelength (λ).

The wave model of light helped to explain some of light's observed properties. For example, the separation of white light into all the colors of the spectrum as it passed from one medium, air, into another, glass, could be rationalized if each color of light "traveled" at a unique frequency. Though the different colors of light will travel at the same speed in a vacuum, in any other medium they will travel at unique speeds. The denser the medium, the greater the difference in velocity of different wavelengths of light. Thus, when light traverses a boundary between two media of different densities, such as air and glass, a separation into the various colors is observed. This phenomenon is known as dispersion.

The high energy and high frequency of shorter wavelength light also explains the aggression of the ultraviolet. The propensity to be absorbed by and cause damage to materials, generally increases as wavelengths decrease. Figure 4 shows the relative photon energy as a function of wavelength. Note the sharp increase in photon energy as the wavelength of light decreases. Though infrared light at longer wavelengths has less energy, studies have shown that its presence, which tends to elevate specimen surface temperature, is critical to the rate of weather-related degradation.[2]

Radiometric and Photometric Quantities and Units

Radiometry is the discipline concerned with the measurement of radiant energy within the optical spectrum, including the UV and IR. Photometry is the measurement of the visible portion of the optical spectrum. More precisely, photometric measurements are weighted for the response of the human eye, the so named V(λ) response is shown in Figure 5, while radiometry measures the total power at all wavelengths of interest. Though photometry preceded radiometry by centuries, today it is regarded as a special branch of radiometry. This is due to the fact that photometric quantities can be derived from radiometric measurements by convolution with the V(λ) curve, shown in Equation 3, where P(λ) is power in Watts per unit wavelength interval.

$$\text{Luminous Flux} = \int V(\lambda)\, P(\lambda)\, d\lambda 1 \qquad \text{[Equation 3]}$$

All measurement of radiation is basically concerned with the quantification of flux (ϕ_e)—that is, the time rate of flow of radiant energy. It is measured in units of radiant power, Watt, and can be expressed as:

$\phi_e = dQ_e/dt$ [Equation 4]

where Q_e is the symbol for radiant energy.

Table I shows the common terms associated with light measurement along with their respective radiometric and photometric units.

Unit	Generic	Radiometric	Photometric
Flux	Flux, ϕ	Watt, W	Lumen, 1m
Incidence (Irradiance)	ϕ/Unit Area E	W/m^2, E_e	1m/m^2, E_v (LUX)
Exitance (Radiance)	ϕ/Unit Area M	W/m^2	1m/m^2
Radiant Exposure	(ϕ/Unit Area)·time	J/m^2	J/m^2 (LUX·s)
Intensity	ϕ/Unit Sold Angle I	W/sr	1m/sr
Sterance	ϕ/Unit Area & Unit Solid Angle L	W/m^{2}sr	1m/m^{2}sr

Table I: Radiometric and photometric terms and units

*Note: Those running weathering tests are often interested in the relationship between the units and how they can be used in calculations of radiant exposures in various units and in different portions of a spectrum. Please refer to "Shedding Some Numbers on Light" (*Sun Spots, *Winter 2001, Vol. 30, Issue 64) for a more complete treatment of this subject and some specific examples.*

Means of Light Measurement

The term radiometer is generically used to represent any instrument used to measure radiation. These instruments cover a wide range of sophistication and applicability. Regardless of their class, to be useful they must demonstrate acceptable performance in the areas of linearity, cosine response, and drift.

The Commission Internationale De L'Eclairage (CIE) in its Technical Report, "Methods of Characterizing the Performance of Radiometers (Photometers)," defines linearity as follows:

> Linearity: Linearity of a detector is the property that the output quantity of the detector is proportional to the input quantity. Then the responsivity is constant over a specified range of inputs.
>
> Note 1: A detector is usually linear over a certain range of input levels. Outside this range it may become nonlinear. The range must be stated.
>
> Note 2: The linearity range of a detector may be affected by the use of unsuitable electronic circuitry.

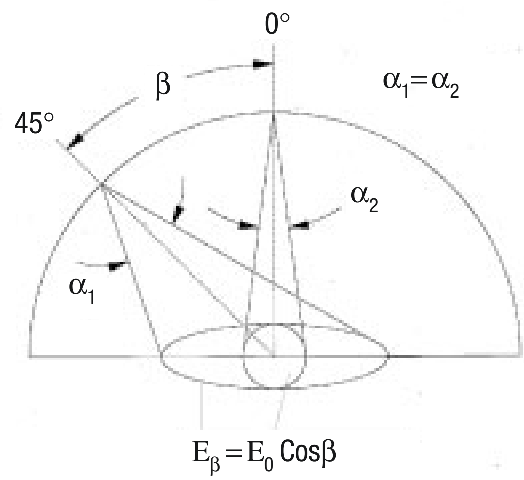

Figure 6: Cosine response

Good linear response is paramount for radiometers designed to record sunlight that varies by orders of magnitude daily.

Irradiance is dependent on the angle of incidence—the angle between the normal to the illuminated plane and the axis of the incident beam. This is an important property of irradiance. In Figure 6, the irradiance (E_β) for an incident beam that is off the normal is given by:

$$E_\beta = E_0 \cos\beta \quad \text{[Equation 5]}$$

where E_0 is the irradiance for $\beta = 0$ (normal incidence), and β the angle of

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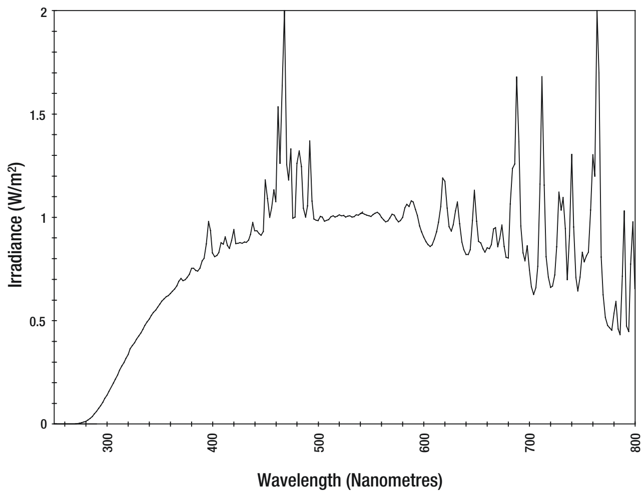

Figure 7: Spectroradiometer irradiance measurement of a Xenon arc lamp

incidence. Ideally, a radiometer for irradiance measurements should receive radiation proportional to the cosine of the angle of incidence. Practically, most radiometers deviate from ideal cosine response, especially at larger angles of incidence. Since poor response can lead to significant error, care must be exercised to avoid instruments that do not meet the minimum recommendation of +/- 5% of ideal cosine response.

Every radiometer experiences a change in its responsivity commonly referred to as "drift." Short-term drift is usually related to external factors like changing ambient temperature, while long term drift is a function of the stability of a radiometer's components. It should be noted that UV radiation also has a deleterious effect on a radiometer's optics, which is a primary cause of drift. Consequently, to stabilize a system many radiometers' optics are subjected to significant radiant exposure (burn in) before being calibrated and placed in service. Obviously, the quality of any radiometer depends largely on how successfully drift is minimized. Provided it is gradual, regularly scheduled calibration may effectively compensate for long-term drift. Short-term drift is generally intolerable.

Radiometers typically used in weathering are:

Pyranometer

Pyranometers measure light indirectly by measuring the temperature difference between a black and white plate, which is proportional to the incident light. These are, by today's standards, old technology, but due to their simplicity can be extremely reliable and are generally more suited for rugged applications than other light measurement devices. Consequently, they are widely used for continuous outdoor measurements.

Filtered Radiometers

Filtered radiometers, commonly used in laboratory weathering devices, typically employ an optical filter that transmits a band of light within the sensitive range of its detector. The filter's transmittance and the detector's spectral sensitivity range together determine the effective spectral response of the filtered radiometer. Equation 6 shows the combined effect of detector responsivity $S(\lambda)$ and the filter transmittance $\tau(\lambda)$:

$$\text{Effective Spectral Response} = \int S(\lambda)\tau(\lambda)d\lambda \qquad \text{[Equation 6]}$$

This can be either a narrow-band or wide-band system depending on the optical filter used. A narrow-band system detects within a narrow spectral region, typically less than 20 nm, full width at half maximum (FWHM). A wide-band system integrates over a broader wavelength region. Detectors used in filtered radiometers range from silicon photodiodes to vacuum phototubes and are selected according to the measurement requirements.

Spectroradiometers

Spectroradiometers are the most sophisticated light measurement devices. They are capable of quantitative and qualitative light detection, measuring a source's power at discrete wavelengths over a spectral range.

$$\text{Total } P = \int P(\lambda)\, d\lambda \qquad \text{[Equation 7]}$$

Figure 7 (previous page) is an example of a spectral power distribution curve (SPD) of a xenon light source as measured by a spectroradiometer.

In its most basic form, the spectroradiometer has a dispersive element (a means to separate light into its spectral components) and a detector. In reality, most modern spectroradiometers are much more complex. A common spectroradiometer system, depicted in Figure 8, consists of several components. The most important are:

Input Optics: The purpose is to integrate and depolarize the light being measured (flux averaging) and to uniformly fill the entrance slit of the monochromator. The preferred receptor is an integrating sphere. The one drawback is its low throughput; typically less than 10% of incoming light is passed on. As a result, the integrating sphere may not be suitable for measuring very low levels of light.

Monochromator (dispersing element): Most employ holographic or ruled diffraction gratings which separate the light. The diffraction grating produces many orders of spectra, as shown in Figure 9. The second and third order spectra are a major cause of stray light in the monochromator, which can cause significant errors in spectroradiometric measurements, particularly when measuring the UV portion of the spectrum. Any spurious signal (noise) will have a more significant error impact on the inherently lower signal levels of the UV. Higher quality instruments employ a double monochromator configuration to address this problem. Figure 10 (next page) illustrates a typical double grating monochromator. An intermediate slit, placed in the light path between the gratings, serves to block the second-order spectra. To facilitate greater spectral purity and wavelength accuracy, the conveyed first-order spectrum is further dispersed by the second grating. The exit slit passes on discrete bands of the spectrum, determined by the positioning of the gratings, relative to one another and to the detector. By providing the gratings with a means of rotation, the entire spectrum can be scanned in small increments. The configuration of the monochromator, specifically the size and placement of the slits in the light path, determines the effective wavelength resolution of the overall system.

Detector: Depending on the intended use, a spectroradiometer is equipped with either a silicon photodiode or the more complex photomultiplier tube (PMT). Silicon photodiodes are convenient and perfectly suitable for visible and IR measurements, but their

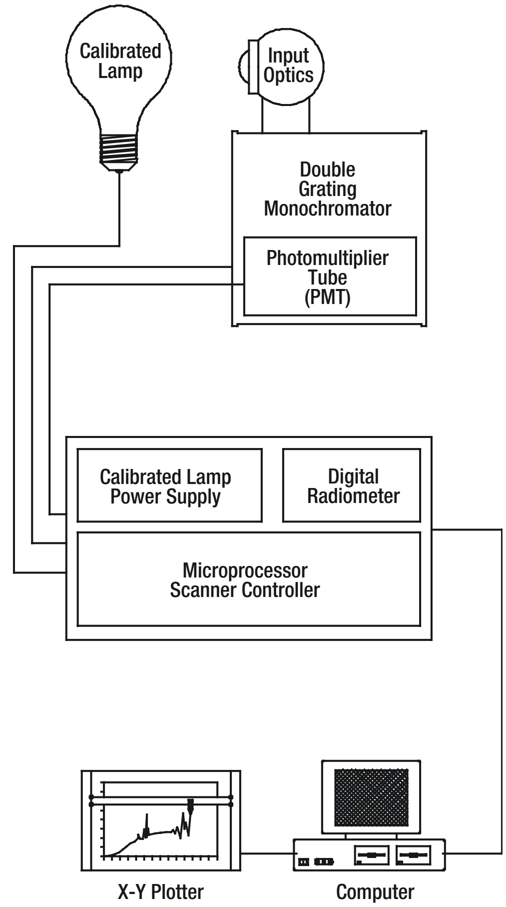

Figure 8: Spectroradiometer system block diagram

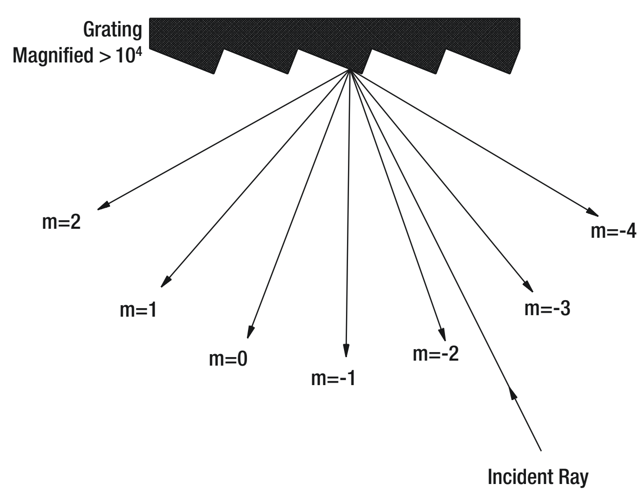

Figure 9: Multiple diffraction orders for a single wavelength

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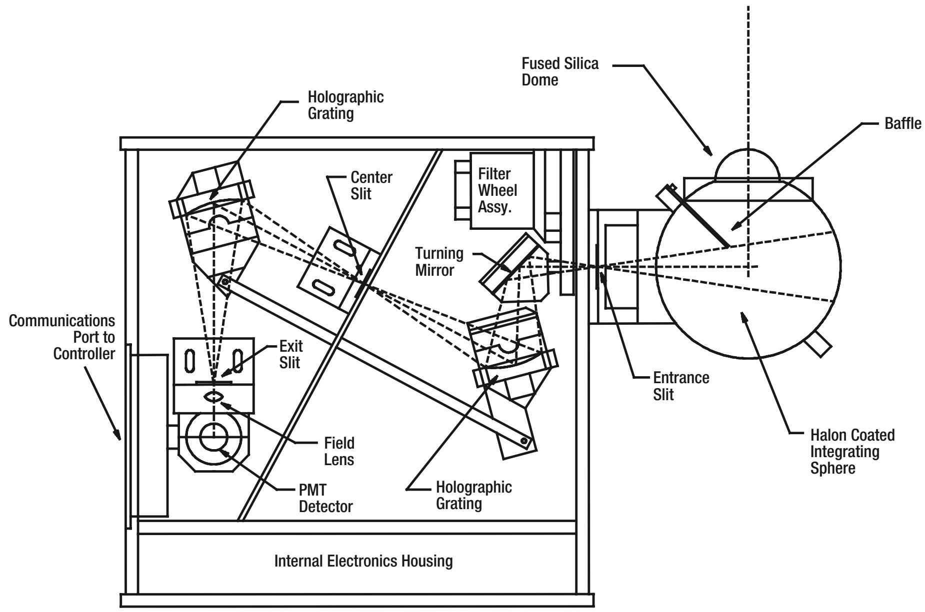

Figure 10: Double grating monochromator schematic

responsivity decreases dramatically with decreasing UV wavelengths. On the other hand, PMTs have proven to be very effective for low light level measurements as well as having an extremely wide dynamic range. The signal from a PMT may be amplified by a factor of up to ten thousand, provided an extremely stable high voltage is supplied. These properties make the PMT ideal for UV measurements. The PMTs drawbacks are its mechanical complexity and sensitivity to temperature changes. Compensation for this temperature sensitivity is usually built in or recommended in most modern systems.

Radiometer Calibration

The objective of the calibration of electro-optical instrumentation is to obtain a functional relationship between the incident flux and the instrument output. A relationship that may be expressed by the calibration equation:

$$\phi = \tau\,(1/R) \qquad \text{[Equation 8]}$$

where ϕ is the radiant entity of interest, for example irradiance, τ is the instrument output and $1/R$ is a constant term known as the inverse instrument responsivity.[3]

Some general rules to observe for good calibration:

1) Ideally, calibration should be carried out such that the measured value is independent of the source's instrumentation.
2) Calibration should be conducted under conditions that reproduce, as completely as possible, the conditions under which the measurements are to be made. Spatial or geometric considerations have a direct bearing on radiometric measurements, and their impact must be taken into account during calibration.
3) Radiometric calibration should be reported with pertinent information regarding conditions of the calibration. This should include a statement of uncertainty, a description of the calibration procedure, and identification of absolute reference standards.

Measurement of Light in Artificial Weathering Instruments

Ideally, any laboratory weathering equipment must demonstrate repeatability and reproducibility. Given the importance of light in weathering, a laboratory weathering device should ensure the user capability to duplicate the radiant dosage from test to test. This is particularly important for the actinic short wavelength ultraviolet. Not only is the UV the most destructive part of the spectrum in weathering, but it is also inherently the most variable.

It is virtually impossible to fully compensate for any loss of UV irradiance, regardless of quantity. However, the majority of modern weathering devices offer some form of irradiance control, where there is a means of monitoring and compensating for changes in the UV. Xenon arc sources have been preferred in weathering instruments for many years; not only are they a good match for sunlight, but quality xenon sources also maintain a relatively stable spectrum with input power changes. This latter property of xenon lends it well to irradiance control.

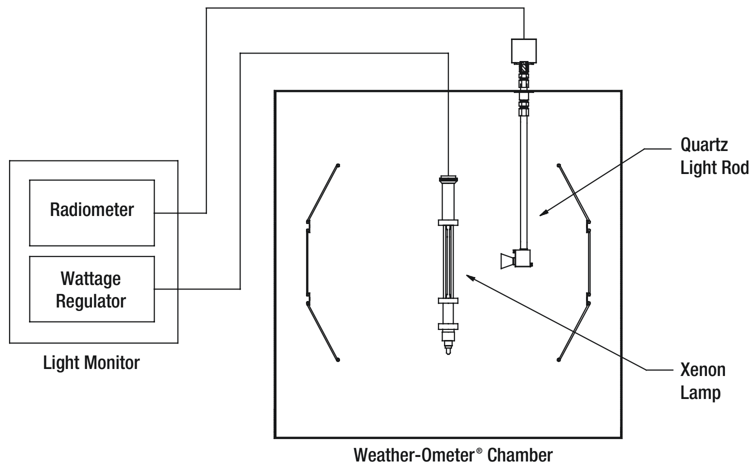

Figure 11: Controlled irradiance system

An example of how controlled irradiance is accomplished is represented in Figure 11. A quartz rod transmits light to a radiometer located outside the hostile conditions of the test chamber. Within the housing of the radiometer, as shown in Figure 12, light first passes through an interference filter and then onto a silicon photodiode which generates a signal proportional to the incident light. The signal from the photodiode is conditioned and used to calibrate the instrument's internal radiometer. Once calibrated, the signal is constantly compared to a user-selected irradiance set point; if any correction is required, the source's power automatically adjusts to the lamp's irradiance at specimen plane, to be equal to the set point.

Controlled irradiance devices typically feature automatic calculation of radiant exposure, since radiant exposure (e.g., kJ/m^2) is the time integral of irradiance (W/m^2). Therefore, simply integrating the measured irradiance over the duration of the light portion of a particular test yields its radiant dosage.

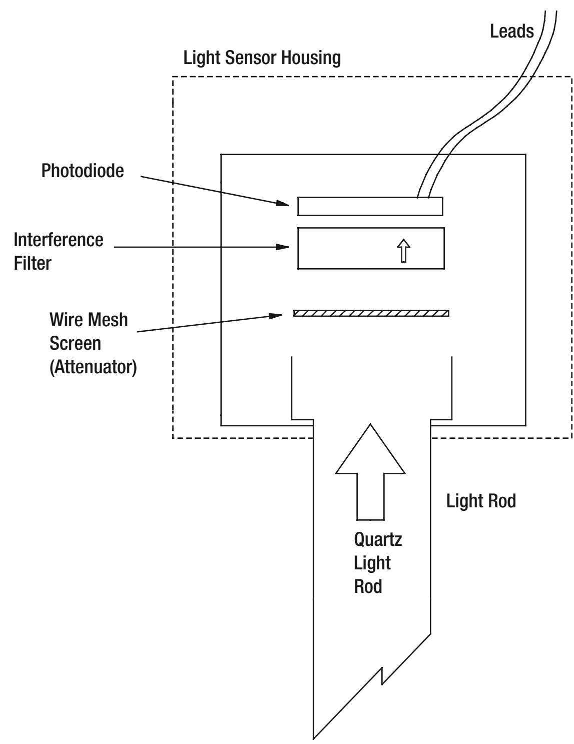

Figure 12: Light monitor sensor housing

Calibration of Light Monitors in Weathering Instrumentation

In addition to the general guidelines for radiometric calibration previously discussed, there are other considerations for the calibration of light monitoring systems in an Atlas Ci Series Weather-Ometer®. The output of the calibrated lamp is dependent on the power it is supplied, therefore great care must be taken to perform initial and all subsequent Wattmeter calibrations as accurately as possible. Any alteration of the environment (geometry) will impact the calibration. This would include, for instance, using the calibrated lamp in an instrument for which it is not intended, as well as performing a calibration in an instrument that has samples mounted on its exposure rack. Care also must be exercised to

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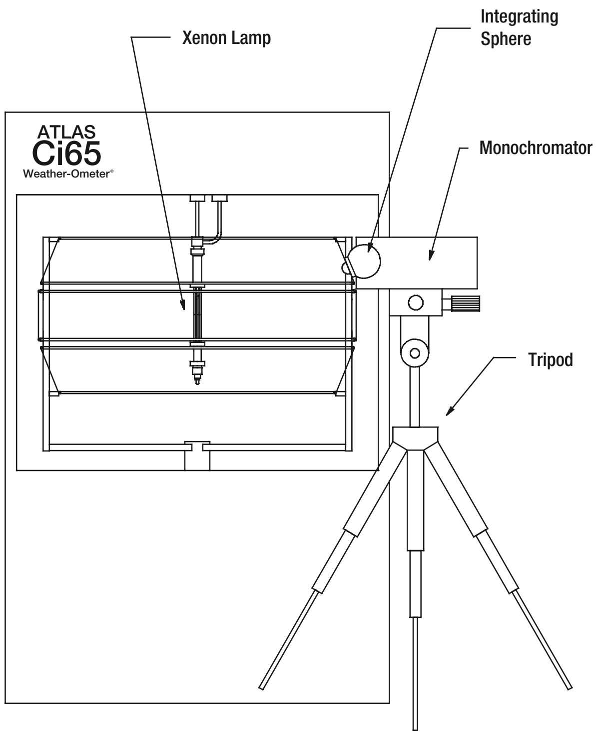


Figure 13: Spectroradiometric measurement in the Weather-Ometer® chamber

not compromise the integrity of the lamp, either by its mishandling or overuse. Calibration values assigned to irradiance standards are only valid for a finite period of time, which should be specified by the lamp supplier.

Following is the basic procedure for the calibration of light monitors in weathering instrumentation:

1) A spectroradiometer must be calibrated using a reference irradiance standard traceable to the National Institute of Standards and Technology (NIST). Primary standards from the government laboratories of any industrialized country are equally suitable.
2) The spectroradiometer is then used to measure a stabilized source, xenon for example, identical to the type used for the testing. This measurement is made *in situ* or in a chamber of identical size and configuration (geometry) as that in which the standard will be ultimately used. The set-up for this procedure is shown in Figure 13.
3) The value measured by the spectroradiometer is the irradiance in W/m^2 (ϕ) in the calibration equation [8]; the τ for the built-in radiometer is adjusted so as to display the calibrated irradiance value.
4) Concurrently, the lamp measured is assigned the spectroradiometer measured value E_e. It can then be used to perform subsequent calibrations of an instrument's built-in radiometer, thereby establishing the traceability of the light monitor to NIST. The chain is summarized in Table II.

Step Number	Procedure
1	Spectroradiometer calibrated from 1000W tungsten calibration standard obtained from NIST
2	Xenon lamp irradiance measured with calibrated spectroradiometer
3	Xenon lamp run in a Weather-Ometer® light monitor adjusted to agree with calibrated irradiance value

Table II: Chain of NIST traceability in light monitor calibration

Conclusion

Light, especially the ultraviolet portion, plays a very significant role in the photochemical degradation aspect of weathering. In the discipline of weatherability testing, both natural and laboratory, it is important to have at least a working knowledge of light and its potential to cause chemical reactions in materials. In order to make meaningful evaluations and analyses of weathering tests, it is necessary to quantify and control radiant exposure when possible. Therefore, tests must be well-designed, incorporating appropriate and accurate means of characterizing and quantifying the light to which test samples are exposed. ■

References

1 Thomas B. Brill, *Light: Its Interaction with Art and Antiquities.* New York, N.Y.: Plenum Press, 1980 [3–4].
2 Richard M. Fischer, "Surface Temperatures of Materials in Exterior Exposures & Artificial Accelerated Tests," ASTM Symposium on Accelerated and Outdoor Durability Testing of Organic Material, STD1202 (1994).
3 Clair L. Wyatt, *Radiometric Calibration: Theory and Methods,* (New York, N.Y.: Academic Press, 1978), [4–5]

Save a Tree—Go e!

In an effort to expand our "Save a Tree—Go e" program, Atlas Weathering Services Group will soon offer electronic weather summaries to our customers. This new service will allow you to receive information on important AWSG news and products right on your computer screen, along with the monthly weather data summary.

To join our "Save a Tree—Go e" campaign, contact John Wonders at **jwonders@atlaswsg.com** with your e-mail address. You will automatically begin receiving the summaries when this new service is rolled out.

Keep in mind that you can always visit the Atlas Weathering Services Group's web site at **www.atlaswsg.com** for weather summaries, technical papers, services, products, and more. ■

QuickTemp™ Improves Garment Testing at JC Penney

Technicians at the JC Penney Lab in Carrollton, Texas, USA, have found a better way to maintain temperatures in 20 of the washing machines they use for fabric testing: QuickTemp technology from Raitech Inc., Partner of Atlas Textile Test Products.

Lab Engineer Carlos Barge said his lab recently bought four QuickTemp and two multi-port QuickTemp Plus™ units. These microprocessor-controlled units, using in-washer sensors, maintain separate wash and rinse water temperatures to within one degree of those specified by AATCC and other test methods. The units overcome variations between machines and seasonal changes in water temperature.

Atlas' multi-port QuickTemp Plus™ makes fabric testing a breeze.

According to Barge, the new units have enabled technicians to improve the speed and the quality of various tests such as dimensional stability and shading. The lab tests both finished JC Penney garments and piece goods.

"Our technicians no longer have to manually measure machine water temperatures like they used to," Barge said. "Since QuickTemp units control temperatures automatically, that frees them to spend time measuring in and measuring out garments. That improves overall testing speed and lab productivity."

"We really appreciate how easy QuickTemp units are to use and how accurate they are," he added. "We're getting tests done faster and with higher quality than we ever have before."

For more information regarding the QuickTemp or other Raitech devices, contact your local Atlas Sales Representative. ■

VIEEW® Now More Appealing than Ever

Atlas is now bundling several new VIEEW® features and offering them as part of a specially priced package: 1) the basic VIEEW device for digital image analysis, an indispensable instrument for objective inspection of surface defects, 2) the fully automated X/Y sample stage and, 3) a software module you select to meet your specific application needs.

The combination of sturdy hardware and intelligent software makes VIEEW an ideal tool for detecting and evaluating structures on material sample surfaces—such as (but not limited to) coated or painted samples—quickly, precisely, and with reproducibility.

The newly developed X/Y stage offers the possibility to scan larger areas up to 150 x 200 mm. The X/Y stage moves the sample over the sample port of the VIEEW instrument. By taking multiple images of the region of interest, the inspection area is scanned, and the individual images are then automatically joined into one large image.

The analysis and classification of this large image is performed in accordance with standards or customers' specifications used for visual evaluation.

While the development of standards for digital image analysis continues, Atlas plays an active role in the technical committees developing these standards. Atlas will continue to communicate with all VIEEW users about these developments.

For more information about this special offer, please contact your local Atlas Sales Representative.

Atlas' new VIEEW® package: A deal you can't afford to miss.

Redesigned BST Sensor Keeps Testing Up to Speed

Atlas had introduced a completely redesigned Black Standard Temperature (BST) calibration sensor for all XENOTEST and SUNTEST instruments.

In the past few years, technology for measurement and control of parameters in our weathering instruments has continuously improved. Simultaneously, the test requirements of our customers have become more sophisticated. Naturally, these trends require better calibration tools. The new **XENOCAL BST calibration sensor** meets these new, advanced requirements.

The XENOCAL BST sensor is used:

- to calibrate the BST measurement of the XENOSENSIV sensors in XENOTEST Alpha and Beta
- to calibrate the BST measurement in SUNTEST XLS+ and SUNTEST CPS+
- to measure temporary BST in XENOTEST instruments that are not equipped with XENOSENSIV (e.g. Xenotest 150 S+)

Atlas' XENOCAL meets new advanced requirements.

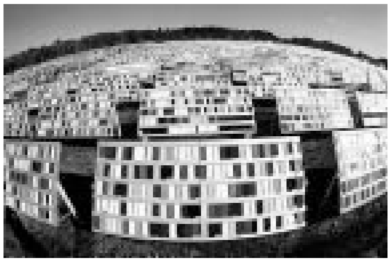
As the name indicates, the XENOCAL BST sensor uses the sophisticated technology of the newly designed XENOCAL sensor and offers the following technical advantages:

- Data logger stores data for 100 days when measuring once per minute.
- Transfer of data to PC via interface enables the user to process the data, e.g. into MS Excel.
- Same battery type for XENOCAL BB 300–400 (UV), XENOCAL WB 300-800 (Global), and XENOCAL BST sensors.
- Resolution improved to ±0.1 °C.

For further information on the new XENOCAL BST sensor, please contact your local Atlas Sales Representative.

AtlasWeathering Services Group

It's Summer All Year!



Test sites in Florida and Australia bring you EverSummer.

Is a faster time to market important to you?

Atlas Weathering Services Group (AWSG) is pleased to introduce a new service, the **EverSummer** program. This service allows our clients to expose their specimens in Miami, Florida, USA, and Townsville, Australia, to achieve a two-summer exposure in one 12-month period. This reduces your material development and validation time, ultimately lowering your development costs. With the need for "faster" data and quicker times to market, you can't afford not to take advantage of this program.

Does your product have what it takes to last?

It is widely acknowledged that the summer months are the most brutal months for material durability. The combination of high ultraviolet radiation, high temperatures, and increased moisture levels in sub-tropical environments is what can "make or break" a material. The sub-tropical climates of Miami and Townsville are widely accepted as benchmark climates for material durability testing. With similar climates, they are the perfect places to achieve two comparable summer exposures in one year.

How will this work?

Summer exposures will be performed in Miami from March 21 through September 21 each year. Upon the conclusion of the Miami summer (September 21), the specimens will be sent via express delivery to Townsville, just in time for the start of summer in the southern hemisphere. The specimens will then be returned to Miami on March 21 for continued exposure or returned to our clients. This unique service is only available from AWSG as a result of our Worldwide Exposure Network. This network consists of over 25 exposure sites in different countries around the world.

For more information on this exciting new service, please contact Richard Slomko at **rslomko@atlaswsg.com** or your Client Services Representative at +1-800-255-3738.

Note: Radiant energy and other comparison data available online at www.atlaswsg.com.

Rich Olsen Joins DSET Staff

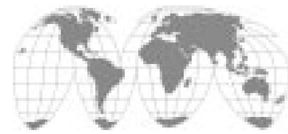
Atlas Weathering Services Group is happy to announce the appointment of Richard Olsen as the new Weathering Manager at DSET Laboratories. Rich holds a B.S. degree in Chemistry from Arizona State University and an A.A.S. degree in Quality Technology from Mesa Community College. Most recently, Rich received a certificate in Global Leadership from the Executive Education Department at Thunderbird, the American Graduate School of International Management.

Rich has spent the majority of his career managing quality, chemical, and environmental laboratories in the electronics industry. His achievements include designing and implementing a new quality laboratory and licensing an environmental lab with the State of Arizona. Rich has also been active in various standards organizations over the years.

Effective January 1, 2003, Tom Anderson left his position as Site Manager to pursue sales support opportunities within AWSG. Thus, Rich will be solely responsible for managing all testing department personnel and day-to-day activities in Static, Evaluation Services, EMMAQUA®, and IP/DP Automotive Testing at the DSET location.

Rich is excited about this opportunity to work in the unique scientific field of weathering. Please join us in welcoming Rich to the AWSG team!

Korea Institute to Join the Atlas Network



Atlas Weathering Services Group is pleased to announce the newest addition to the Atlas Worldwide Exposure Network (WEN)—Korea Institute of Construction Materials (KICM). AWSG and KICM signed a joint agreement (effective November 1, 2002) to partner in materials testing research and the development of weathering test methodology. In addition, AWSG will offer technical expertise in the design and development of the KICM outdoor exposure site.

WEN offers outdoor weathering sites around the world to ensure exposure to a variety of climates and address characteristics of specific markets or regions. The new KICM site will be built in Seosan, Korea, a typical light industrial, marine environment commonly found along Korea's coastline. Seosan also sees migrant pollutants from China's east coast, offering a unique high pollutant and corrosive marine microclimate. The KICM site is a perfect addition to Atlas' worldwide network. KICM has future plans to develop more sites around the Korean peninsula to highlight other micro environments common to Korea, such as a heavy industrial climate and more generic UV weathering climate.

In addition to the new WEN site, the joint agreement will encourage the exchange of researchers and information in the development of reliability assessment for materials durability. With AWSG's expertise in materials weathering and KICM's knowledge of all types of construction materials, this partnership is the perfect union to study material reliability.

With this great addition to the AWSG network and a broad scope of test methods and equipment, AWSG delivers the technology and service you need to achieve a quality product, a competitive edge, and a faster time to market.

For more information regarding testing in Korea, please contact your local Atlas representative or call AWSG directly at +1-623-465-7356.

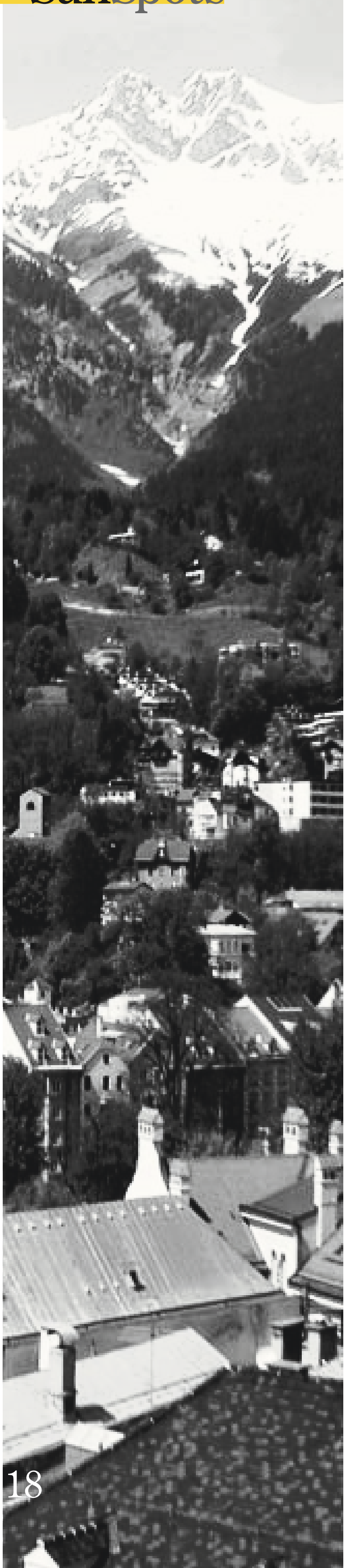
AWSG Changes Representation in Korea

Atlas Weathering Services Group will change representatives in Korea effective April 1, 2003. **M-C Corporation,** the current Korean representative for Atlas instruments and products, will add AWSG services to their list of offerings. This change further supports the Atlas Network of Weathering strategy and will better serve our clients through the use of a single representative for all Atlas products and services in Korea.

Joongwon International Corporation has been an outstanding and successful representative and will work closely with M-C Corporation in the transition of AWSG support. Joongwon will continue to focus on their successful core business.

We thank Joongwon for their years of support and welcome M-C Corporation as the new AWSG representative.

For additional information, please contact your local Atlas Sales Representative or contact AWSG directly at info@atlaswsg.com.



AtlasCommitment to Education

Courses Introduced in Switzerland and Germany

Atlas offers two types of Fundamentals of Weathering courses, from basic to advanced, to support the training needs of our customers:

The **Fundamentals of Weathering I** is a basic, one-day seminar offered at various locations around the world. It focuses on lightfastness and weathering durability testing techniques and introduces how various factors of weather and climate may affect materials.

The **Fundamentals of Weathering II** is a continuation of the basic, one-day seminar that examines in more detail how various factors of weathering and climate may affect materials and how to test the resistance of a formulation or product to those factors. Measuring devices for light, temperature, and moisture are identified, along with some of the common errors associated with their use.

Students attending the Fundamentals of Weathering II will learn more about the primary weather factors that affect the durability of materials and will acquire a more in-depth understanding of the photochemistry processes occurring during weathering tests. From choosing the appropriate test to analysis and evaluation techniques, students will leave the class with in-depth insight into the weathering industry.

The Fundamentals of Weathering II has been offered in France since 2002; Atlas is pleased to announce that it will now be offered in Germany and Switzerland beginning of May 2003.

For more information, contact Bruno Bentjerodt at ATLAS MTT GmbH, tel.: +49-6051-707-245, email: **clienteducation@atlasmtt.de,** or visit our web site: www.atlas-mts.com.

2003

Fundamentals of Weathering*
April 22
Toronto, Canada

April 29
Lochem, The Netherlands (English)

May 21
Switzerland (German)

June 10
North of England

June 10
Marlborough, Massachusetts, USA

June 12
Baltimore, Maryland

June 12
South of England

June 17
Lochem, The Netherlands (German)

June 19
Paris, France

August 19
Kansas City, Missouri, USA

September 24
Detroit, Michigan, USA

November 14
Research Triangle Park, North Carolina, USA

Fundamentals of Weathering II
April 23
Toronto, Canada

June 18
Lochem, The Netherlands (German)

May 21
Switzerland (German)

June 20
Paris, France

August 20
Kansas City, Missouri, USA

Weather-Ometer® Workshops**
(All Weather-Ometer workshops are held in Miami, Florida, USA)

May 19
Ci4000/Ci5000 Weather-Ometer® Workshop

May 20–21
Ci35/Ci65 Weather-Ometer® Workshop

October 20
Ci4000/Ci5000 Weather-Ometer® Workshop

October 21–22
Ci35/Ci65 Weather-Ometer® Workshop

October 23
Advanced Ci35/Ci65 Weather-Ometer® Workshop

Ci and Xenotest Workshops
June 16–17
Ci Workshop
Lochem, The Netherlands (English)

June 22–23
Ci Workshop
Lochem, The Netherlands (Dutch)

June 24–25
Xenotest Workshop
Linsengericht, Germany (English)

November 24–25
Xenotest Workshop
Linsengericht, Germany (German)

Registration information and workshop/seminar brochures are available from Bruno Bentjerodt, Client Education Europe, 0049-(0)6051-707-245 or bbentjerodt@atlasmtt.de.

* *Effective immediately, if you attend any Fundamentals of Weathering course and purchase an Atlas Weather-Ometer® with 12 months, Atlas will reimburse you for the full value of the seminar. Offer good on all Atlas Ci models and Xenotest Alphas, Betas, and 150 S+s.*

** *All Weather-Ometer workshops take place in Miami, Florida at Atlas' South Florida Test Service location. Registration is available online at www.atlas-mts.com or by contacting Theresa Schultz at +1-773-327-4520.*

For more information, please contact your local Atlas representative.

Atlas Labs Earn German DAR Accreditation to ISO 17025

Atlas laboratories offer the most accelerated, up-to-date testing, including in our air-cooled Xenotest Alpha.

Atlas is proud to announce that two test laboratories within ATLAS MTT GmbH were accredited recently by the Deutscher Akkreditierungsrat [DAR], an internationally renowned accreditation council affiliated with the Federal Institute for Materials Research and Testing of Germany:

ATLAS MTT GmbH in Linsengericht (D)
Test laboratory for radio- and photometric measurements
(DIN EN ISO/IEC 17025:2000) DAP-PL-3574.00

Its decades of experience with optical systems and its professional expertise make it an indispensable partner to calibration service and quality assurance at our manufacturing site. By achieving the DAR accreditation, Atlas can provide clients with independent proof that all applied products and methods as well as measuring and testing results, are objective and transparent. This is important to ensure the quality of the products we manufacture and the services we provide—in our laboratory or on site.

We are accredited to measure:

- the spectral irradiance of lamps and instruments in the wavelength range 250 nm to 800 nm
- the illuminance of lamps and instruments

Furthermore we have the expertise to optically measure:

- irradiance of lamps and instruments in the wavelength range 250 nm to 1600 nm with various spectroradiometers
- total radiation in a wavelength range 305 nm to 2800 nm with a pyranometer
- spectral transmission in a wavelength range 200 nm to 1600 nm
- color temperature, color rendering, and color location of lamps

ATLAS MTT GmbH in Duisburg (D) with Labs in Duisburg (D) and Lochem (NL)
Accredited test laboratories to carry out tests in the fields of: performance and load tests against light- and weatherfastness and aging of plastics, paints and coatings, sealings, rubber, automotive exterior and interior materials and components, printing inks, glues, anodised aluminium, and non-metallic materials by natural and artificial weathering and exposure to artificial radiation
(DIN EN ISO/IEC 17025:2000) DAP-PL-3551.99

For many years, our labs in Duisburg and Lochem have provided reliable test results to international customers. The DAR accreditation stresses the laboratories' obligation to identify clients' needs and ensures the test methods chosen meet those needs.

The facilities in Germany and The Netherlands conduct accelerated weathering and lightfastness testing. Featuring a variety of xenon, carbon-arc, fluorescent, and metal halide weathering devices, they can meet most accelerated test methods from corporate, national, and international standards organizations.

A fully equipped laboratory for optical property and physical evaluation using the leading measurement instrumentation technology supports our seven-days-a-week laboratory operation. With more than 40 different weathering devices and a highly skilled laboratory staff, the accredited laboratories provide the highest level of service.

Weathering Experimenter's Toolbox: C&C Studies

C&C studies (Control and Capability studies) are an important tool in manufacturing processes. C&C concepts may also be applied to weathering processes and represent an important tool for weathering researchers as well. C&C concepts are especially useful for artificial weathering processes and measurement processes.

Statistical control is usually assessed using control charts. Control charts document process output over time and indicate outputs due to special causes (non-random pattern, trends, or points beyond calculated control limits). Application of control charts to weather data, instrumental measurements, and exposures of materials can characterize these processes for non-random patterns.

For instance, a weathering researcher may choose to expose standard reference materials in accelerated exposures along with test specimens. Control charting the degradation of these standards over many exposures may indicate the predictability and consistency of repeated exposures through time. Weathering researchers often perform repeated measures using standard materials on optical measurement instruments. Simply plotting this data on control charts and analyzing the data for the state of statistical control can offer insights regarding the measurement process.

A capability study compares the distribution of repeated measures to specification limits or tolerances. Process capability indicies (C_p and C_{pk}) express the width of specification limits to the measure of the actual variation of the process. Capability analysis can be easily adapted to accelerated weathering processes. For example, consider a lot of metal halide lamps used for acceleration and specified to cause a degradation of standard material within $\pm 0.5\ \Delta b^*$ units of a target value. If a second set of lamps produces a distribution of degradations outside the $\pm 0.5\ \Delta b^*$ limits, the second set is said to be not capable of meeting the specification requirements.

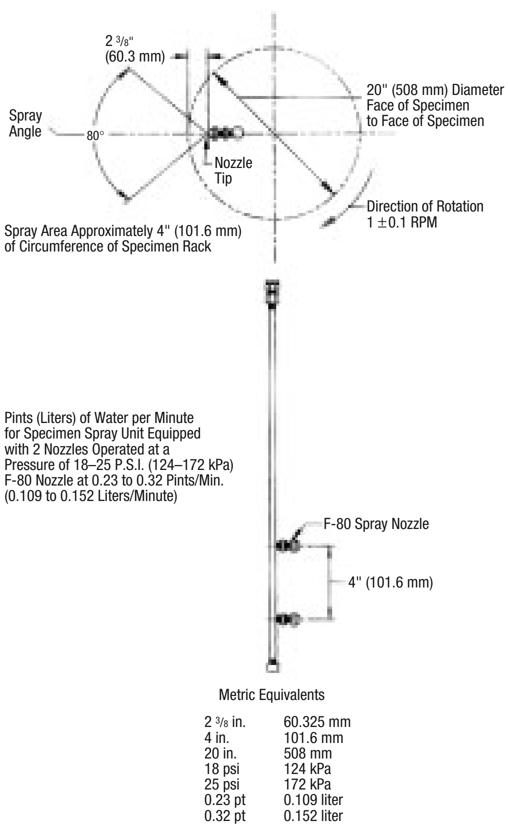
It is important to remember, however, that if a process is not in control, it is difficult to predict what the process will do in the future. Thus, process capability cannot be assessed until a process is in control. ■

Is 'Meeting the Intent' of a Test Method Enough?

As a manufacturer or supplier, is simply "meeting the intent" of a test method enough to get repeatability and reproducibility in the testing of your material? With the changes many standards are undergoing to become more generic as well as the introduction of different test instruments, specifiers need to be more aware of some of the differences in the accelerated weathering and lightfastness equipment currently available.

What does "meeting the standard" mean? First, a standard by definition is "something accepted as a basis for comparison: criterion." The specified conditions outlined in standards are assumed to be important or they wouldn't have been put into the method. People who write the methods spend many hours researching and debating before the method is finalized. Companies that use these methods expect the test instrument manufacturers to produce instruments that will reproduce the conditions of the test method and provide a base for comparison.

ASTM G26



Specimen Spray Arrangement for Type A and AH Apparatus

An instrument that meets the standard will provide repeatable and reproducible test results, while the instrument that claims it only "meets the intent" of the test may not provide the required repeatability. Stating that the instrument only meets the intent of the test immediately signifies that it does not meet the conditions of the test method but, rather, intends to provide some similarity to the conditions.

In order to fully appreciate the unique features of the equipment and how the current changes in the test methods affect your test results, we need to look at some historical information. The intention is not to say that we shouldn't make improvements, but more to clarify the original condition of the test method.

As an example, let us look at the one of the oldest and simplest test conditions for weathering:

Cycle: 102 minutes of light without spray followed by 18 minutes of light and spray. The light source for this test condition has changed from carbon arc to xenon over the years; however, the cycle has remained a constant. The instruments used during the development of this cycle consisted of large chambers in which the light source (carbon arc or xenon) hung in the center. Around this light source was a rotating rack onto which the samples were mounted. This rack then rotated around the light source at a constant rate of 1 revolution per minute. Also installed in this chamber was a spray mechanism that sprayed the samples with water as they passed through the spray.

Considering that the samples are rotating at one RPM and the spray is on for 18 minutes, each sample was briefly wetted as it passed through the spray. Having the spray on continuously for 18 minutes meant that each sample was wetted and dried 18 times during this cycle. Rather simple, but when compared to other instruments on the market that either rotate the sample faster or not at all, we have introduced a variable into the test.

New generic methods simply state that the spray is on for 18 minutes and off for 102 minutes. The implication is, if one has a means of turning the spray on and off for the prescribed time period, the instrument meets the intent of the test. From the above example, one can see that the thermal shock and time of wetting are very different from one instrument to another. Has meeting the intent of the test introduced a variable that prevents or at the least greatly reduces the possibility of repeatability and reproducibility? Absolutely.

Specimen temperature is another area of concern. Historically, samples were mounted on rotating racks that moved through a stream of air. Air flowed both in front and behind the material being tested. If the temperature of a sample rotating in free air is compared to one that is lying flat on a metal tray with air only passing over its front surface. Are the thermal effects the same? We know, from outdoor exposures, that the surface temperature of a sample placed on a backing is several degrees hotter than the same material that is not backed. Has another variable been added to the test? Yes.

The purpose of conducting a test and using a standard test method is to determine and compare the performance of the material being tested. If the instruments being used only "meet the intent" of the test methods, we are limited to the variability in different test instruments rather than the material. Specifiers need to be fully aware of the difference in the instruments available and be certain that they in fact meet the test method and not merely the "intent," which is subject to different interpretations in the first place.

Are You Thinking Globally? Atlas Has You Covered

Countries around the world present myriad climates to which your product will be exposed. They also potentially present different standards that have to be met.

As companies set up production in new parts of the world or look to emerging markets for increased sales opportunities, they will face new challenges in material testing.

Atlas has offices in seven countries, outdoor sites in three countries, sales and service representatives covering 67 countries, and an outdoor exposure network that covers another 12 countries with 22 different sites. With this extensive global coverage, Atlas is ready to support you wherever you need us.

Understanding how your product will last in its end-use environment is critical. The Atlas Worldwide Exposure Network, consisting of 22 outdoor weathering sites, ensures that factors from a variety of climates are available for your testing needs. We are especially proud to announce our partnership with GEARI (Guangzho Electric Apparatus Research Institute) in China and KICM (Korean Institute for Construction Materials) in South Korea. These world-class sites offer Atlas clients the opportunity to see how their products will respond in two very important new markets.

For your accelerated testing needs, Atlas provides local sales and factory-trained service throughout the world. In addition to annual factory training, Atlas personnel travel extensively to ensure that representatives have the most up-to-date training. Through our worldwide contacts, Atlas will be able to provide answers for all of your weathering and textile testing questions.

Whatever and wherever your weathering and textile testing needs are, Atlas is prepared to support you locally while you think globally. Please visit our web site at **www.atlas-mts.com** to find your local Atlas contact.

Visit us at NPE 2003!

Booth #4333
McCormick Place

June 23–27
Chicago, Illinois

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