White Paper

Consumer Electronics Environmental Testing

UV, Solar & Weather Durability

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AMETEK MEASUREMENT, COMMUNICATIONS & TESTING

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Consumer Electronics White Paper

Beyond the Basics – Solar, UV & Weather Durability of Consumer Electronics

About Atlas

Atlas Material Testing Technology, part of AMETEK, Inc., pioneered artificial laboratory light and weather resistance testing in 1915, and leads the industry with the broadest line of related testing instruments and services. Atlas instruments are specified for lightfastness, photo-stability, weathering and corrosion testing by leading global consumer electronics OEMs for both their R&D and global supply chain QA testing due to instrument performance, quality and global technical support.

In addition, Atlas owns and operates outdoor exposure test sites and, together with our international partners, has established the Worldwide Exposure Network of over 20 outdoor test sites. Atlas continues its history of innovation and leadership with a suite of natural and accelerated outdoor weathering testing devices and services.

Note: Due to Atlas' strict confidentiality policy and non-disclosure agreements, information and photos of actual testing of client consumer electronic products (such as smartphones and OLED displays) cannot be shown, nor Atlas client names used or implied, for promotional purposes. Any illustrations are to be considered as industry-representative products only.

Note: The term "CE" will be used in this document as an acronym for "Consumer Electronics". It should not be confused with the European Conformity requirements or the stylized CE Marking symbol: CE

EXPECTATIONS

Each dissatisfied customer will tell 8-10 others about their dissatisfying experiences -translates into lost customers, and makes new customers that much more difficult and expensive to recruit.

What can go wrong?

Understanding and testing materials durability allows you to meet your customer expectations and avoid unanticipated and premature negative changes in the appearance, safety, functionality or performance of your product, and the resulting implications to your brand.

- Plastics can fade, yellow, color shift, crack, lose mechanical and impact strength, become brittle.

Test to be sure

" . . . how do you ensure the quality and durability of your product when it is exposed for an extended period of time under varying environmental conditions?

Environmental testing is the answer to this question."

- Paint & coatings can delaminate, crack, fade, chalk, lose gloss, yellow, color shift.
- Elastomers and rubber can crack, become brittle, become tacky.
- LCD and OLED screens can fail from sunlight UV or moisture exposure.
- Optical and other sensors can degrade from sun or weather exposure.
- Solar-thermal heat load can degrade batteries/electronics.
- Metals and electronics such as connectors and circuits can corrode.

A highly regarded paint scientist at one of the big automotive OEMs provided an excellent analogy for consumer electronics. In short, paint quality sells cars; people by on emotions and then rationalize their decision. If you drive down the street and your radio, power windows and air conditioner don't work, only you know it. But if the paint looks like crap you know it, your neighbors know it, the dog walker knows it, and everyone says, I'm not buying that brand ….

So, after paying perhaps $500-$1000 for your latest gadget, it may continue to function perfectly, but if the consumer isn't pleased with its appearance durability, they may consider another brand in the future, and are more likely to let others know through social media. Remember, it costs far more to acquire a new customer than to keep an existing one.

It's about reducing RISK

Early stage environmental stress testing allows for screening and selection of candidate materials and components such as coatings, films, displays, cases, touchscreens, etc., for durability even before getting to actual early product prototypes. As the design progresses and late-stage prototypes become available, the testing typically moves to a more advanced phase.

As pre-production units progress from basic functional and Engineering Validation Testing (EVT) to Design Verification Testing (DVT) where the units are much closer to the final product vision, testing enters five key areas:

1. Functional usability testing

2. Performance testing

3. Environmental Testing

4. Product reliability testing.

5. Regulatory compliance and safety testing

"Environmental testing", item 3 above, is the focus of this document, specifically the durability testing aspect. There are two distinct aspects to this. The first is in the realm of short term environmental tests and crosses over into several of the other areas. This may include tests such as freeze/thaw, rain penetration or water immersion, "shake and bake" tests, etc., and are designed to determine the operational and destruct limits of the device.

But, we do torture testing . . .

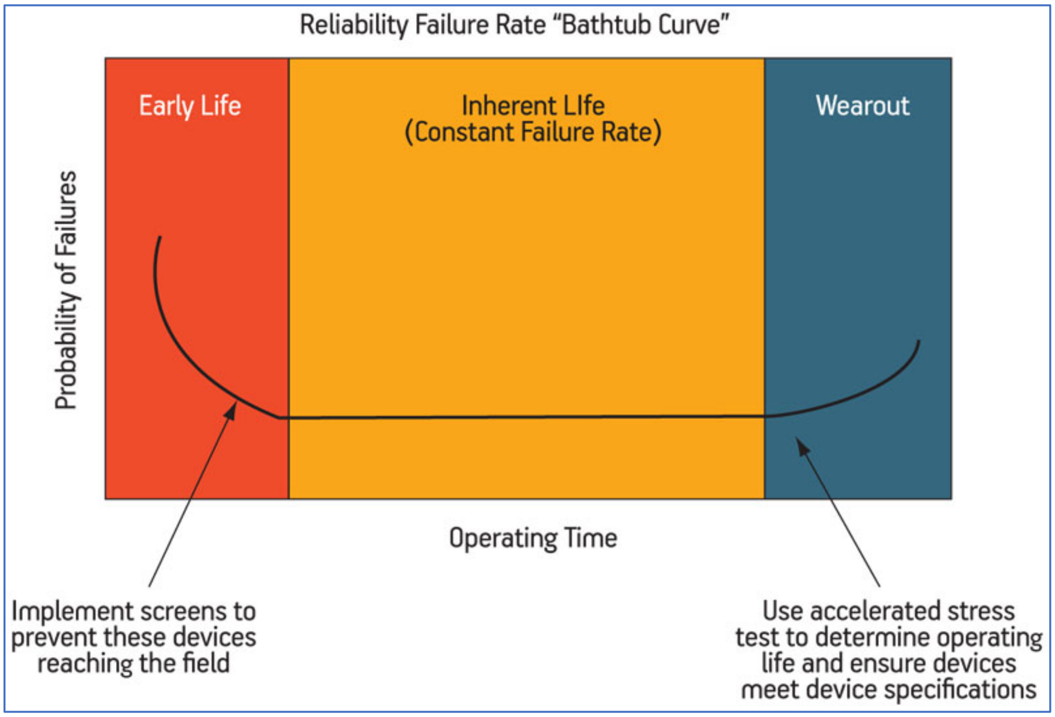
Many, if not most, consumer electronics companies (or suppliers) perform "torture tests". Typically, a torture test subjects the item in question to a variety of severe trials that far surpass anything it would be likely to encounter in real-world service use. Successfully passing such tests can provide the manufacturer and consumer some easily understood assurance of ruggedness and reliability when they pass the tests, or identify areas perhaps needing improvement if they don't. These may also provide potential for competitive comparisons, real or implied. You may recall the iconic American Tourister luggage gorilla ads of the 1970's or the Timex watch "takes a licking and keeps on ticking" series of the 1950's and 1990's reboot as examples of some unrealistic testing leading to a successful marketing conclusion. But these tests won't assure you that your paint or plastic won't fade, yellow or crack, for example.

Testing is a process, not an event . . .

The Product Validation Test (PVT) is performed on the last pre-production build intended to be sold to customers. Production then immediately ramps up to Mass Production (MP). But testing doesn't end as mass production begins. On the contrary, testing needs to continue to happen for as long as the assembly line is still running. Suppliers sometimes change materials, processes may drift, and other factors can affect the product during its production duration, so "surveillance testing" is a necessary ongoing process of a Quality Management System (QMS).

However, extreme torture tests mostly probe for material or design flaws, or "out-of-box" failures likely to be encountered during the early life (a.k.a., "infant mortality") of a product. This is shown as the first area of the classical engineering “Reliability Bathtub Curve” shown below.

Durability testing involves testing for the longer-term degradation of materials, much of which is environmentally influenced. This requires different tests than torture or highly accelerated approaches. This type of testing targets the effects of accumulated heat/light/moisture service exposure on materials. Larger consumer electronics companies now implement environmental stress durability testing for all new products.



Product reliability “bathtub’ curve

The Problem with “Light”

Consumer electronic devices are indispensable to most people, and they want to use them where they live, work, play and travel. Even products once considered as “indoor use” now have mobile counterparts, or have been replaced with mobile technologies such as smart phones.

However, the increasing exposure of consumer technology to various environments, both outdoors and in interior spaces, means that products must be tested for their resistance to the effects of key stresses such as heat, moisture, sunlight, artificial lighting, etc., as these can damage the appearance and/or functionality of products.

The ultraviolet (UV) and short wavelength near-visible light present in daylight can degrade plastics, paints and anodization, optical and other functional coatings, plastic films, and organic materials such as liquid crystal (LCD) and organic light emitting diode (OLED) display elements. Some of this photodegradation affects color and appearance properties (yellowing, color

fade, hue shift, gloss loss), but mechanical properties such as impact resistance can deteriorate, or cracking, crazing and delamination can result.

The problem isn't confined to just the outdoor use of products. Window-glass filtered daylight in homes, business, retail and transportation, and some types of artificial light such as fluorescent bulbs and white LEDs can also photodegrade polymeric and organic materials.

Automotive interiors can be particularly aggressive with the addition of high and low temperature and humidity levels in combination with sunlight.

Note: The term "light" only applies to the portion of the electromagnetic spectrum visible to the unaided human eye. Therefore "sunlight" would only apply to the visible region as well. The term "terrestrial solar radiation" is appropriately used to refer to all wavelengths of solar radiation, including the ultraviolet (UV), visible (VIS) and infrared (IR) portions of the spectrum. However, in lay use, the terms "sunlight", "daylight", etc., are used here to include all the wavelengths in their respective regions and not restricted to the visible portion only. Similarly, "light source" will be used rather than "radiation source".

Durability Aspects of Quality and Reliability

Several terms used in discussing product quality are worth briefly noting. Note the discussion below is primarily for a lay-person's understanding rather than rigid reliability engineering definitions, so some license is taken in this document.

Quality is defined in ISO 8402:1994 *Quality management and quality assurance – Vocabulary (2nd edition)* as "the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs."

Reliability is a measure of how likely or for how long a product or service can perform its intended function without interruption.

Durability is the ability to endure. It measures the amount of use one can get from a product before it deteriorates to some unacceptable level.

Durability and reliability are closely linked, but they are not the same thing. Durability issues can *contribute* to a lack of reliability, i.e., degradation until product failure. However, there are two unique aspects to durability to note. First, a lack of durability does not *require*

QDR

MEANS QUALITY, DURABILITY AND RELIABILITY

ENVIRONMENTAL DURABILITY

"Environmental durability" is a specialized subset of overall durability testing. It concerns itself with the effects of accumulated in-service environmental stresses such as sunlight, artificial light, moisture and heat over time.

"availability of the intended function without interruption", in other words, failure. Instead, durability can be a *reduction* in a property to some level at which it becomes objectionable to the user. This can include purely aesthetic properties which are <u>unrelated</u> to the actual operational performance or function of the item.

In assessing durability, we are often interested in determining both the rate and the degree of undesirable property change under various conditions of service use. These result mostly from "wear out" mechanisms. "Reliability" also considers out-of-box and early "infant mortality" failures as well as the product's resistance to potentially catastrophic in-use events such as water immersion or being dropped. Durability testing looks at generally longer-term in-service environmental exposure. However, once materials are validated for use, shorter term surveillance screening tests can often be used to monitor for problems during the product manufacturing lifecycle.

Durability affects one's perception of value; we expect more from higher cost or premium brand items, but even then, we might accept some change after several years of ownership that we wouldn't after only several months. Therefore, durability is an important parameter which affects one's perception of "quality".

While the distinctions between reliability and durability may seem superficial, they do require very different approaches to test design and implementation.

In general, accelerated reliability testing uses high stress levels to force product failures and extrapolate that data to normal use conditions. Durability testing uses more normally encountered stresses, often in combination, to simulate normal wear out, and does not require product failure.

Understanding the degradation of materials in response to the environments encountered, and their impact on functionality, durability, reliability and performance is the purpose of environmental durability testing.

Acceleration and Correlation in Environmental Durability Testing

"Environmental durability" is a specialized subset of overall durability testing. It concerns itself with the effects of typical in-service environmental stresses such as sunlight, artificial light, moisture and heat over time rather than a one-time occurrence. These stresses are applied in unison, as that is how products experience their environment(s). However, it is highly desirable to have some degree of test acceleration of the normal degradation processes in environmental durability testing, as well as maintaining repeatability and reproducibility in the test exposures. After all, who wants to wait perhaps two years or more under normal use to test a material, part or product for wear out such as color fade? However, in all testing, we really have only two mechanisms available to us for acceleration. These are "overstress" and "time compression". Again, the purpose isn't to try and force a failure under extreme conditions, but rather to determine what degradation might occur under service use conditions.

Overstress is the application of one, or more, stresses, either at peak normally encountered levels or at a somewhat higher level, but nowhere near the "destruct limit" levels often used in reliability testing. The goal is to provide some test acceleration, being careful not to change the degradation mechanisms, which may be changes to material chemistry (e.g., photodegradation of a coating or plastic), or physical (e.g., thermomechanical expansion/contraction) in nature.

Time compression involves minimizing "dead times" in testing. For example, a mechanical pushbutton switch could be tested for wear out by cycling it 10 times per day, if that would be typical. But that could be accelerated by operating it by operating it once every second, for 86,400 cycles per day. In testing for ultraviolet sunlight resistance, for example, we can use continuous light rather than cycling, as with normal daily sunlight.

In practice, often a combination of both overstress and time compression is used to provide some test acceleration.

IN SCREENING FOR ENVIRONMENTAL EXPOSURE EFFECTS FOR MOST CONSUMER ELECTRONIC PRODUCTS, COMPONENTS OR MATERIALS, THREE KEY STRESS FACTORS ARE USUALLY INCLUDED IN COMBINATION.

THESE ARE HEAT, LIGHT AND MOISTURE.

Environmental Durability Stresses

Three key stresses

In screening for environmental exposure effects for most consumer electronic products, components or materials, three key stress factors are usually included in combination. These are heat, light and moisture.

1. Light & Ultraviolet (UV) Radiation

Photodegradation reactions from light can have several negative impacts on CE products and should be tested for resistance. Visible radiation which is technically "light" as well as the ultraviolet (UV) radiation present in both direct and window-glass filtered sunlight and some artificial sources can cause photodegradation resulting in:

- Yellowing of plastics, films, and coatings
- Fading or hue shift of colored materials
- Degradation of plastics and other organic materials resulting in loss of mechanical properties such as impact resistance

- Inactivate UV sensitive materials such as LCD and OLED pixel elements
- Produce appearance changes such as loss of gloss, haze, microcracking, chalking

- The near-infrared heat energy present in sunlight can initiate some of the above as well, and cause sunlight-exposed surface temperatures to rise, leading to thermomechanical stress.

It's not just UV

While UV, such as found in sunlight and some artificial light sources is important, photodegradation can result from other wavelengths as well.

Surface temperatures are also influenced by infrared light.

And higher temperatures drive degradation and also affects moisture.

In testing, it is important to get a realistic balance of these key stresses of the product's service environments.

The spectral irradiance (intensity vs. wavelength) of the light radiation source output will affect the degradation type and rate, and so should be matched to the worst-case expected end-use service environments in testing for the most reliable results. This can include matching direct or glass filtered daylight as well as artificial light sources.

2. Heat

Elevated temperatures can induce thermal degradation of organic materials such as films, coatings and plastics, and increase the rate of light-induced degradation. Elevated temperatures can also weaken adhesives and gaskets, and temperature cycling can induce thermomechanical stress. External sources include both ambient temperature and the effect of heat load on CE products exposed to sunlight, including inside buildings and automobiles. The combination of elevated heat and moisture can be particularly destructive to many materials.

3. Moisture

Moisture is largely underappreciated contributor to the degradation of organic materials. Water, either as liquid (including condensation and rain) or as humidity, can degrade some organic coatings and polymers (hydrolysis), and can affect moisture sensitive components such as OLEDs. Moisture levels inside closed, parked vehicles can rise to over twice ambient outdoor conditions; in combination with elevated temperatures this can affect many electronic components and increase corrosion rates as well as affect organic materials.

These three key stresses, when experienced outdoors, are called "weathering" and when encountered indoors (even in a vehicle) are usually called "lightfastness" in the testing industry. Certainly, environmental factors such as "freeze/thaw" cycling or exposure to chemicals, such as cleaning agents, can be encountered. These are usually best tested with reliability engineering "torture tests" and are rarely used in durability assessment tests, especially at the materials and component level.

Testing UV Resistance, Lightfastness and Weathering

Specialized accelerated artificial weathering chambers are specifically made for this type of testing. Generally, these contain a source of radiation ("light source"); this is usually a xenon arc gas discharge lamp, tuned by various optical filters to expose test specimens to one of three spectral conditions:

- Full-spectrum simulated outdoor sunlight (a.k.a. terrestrial solar radiation) consisting of the ultraviolet, visible and near-infrared regions of the spectrum

- Full spectrum window-glass filtered simulated sunlight, typical of building or vehicle interiors

- Artificial indoor lighting characteristic of windowless interior rooms or retail stores

Devices for laboratory environmental testing were pioneered and have been continually developed by Atlas since 1915, making Atlas the global leader in this technology.

The irradiance (i.e., light intensity) in these devices, depending on the test conditions or method selected, generally ranges from typical in-service maximum to up to about threefold higher for direct or glass filtered sunlight. For interior lighting, which is far less bright, the intensification factor can be from one hundred to one thousand or more.

The Unit Under Test (UUT) surface temperatures in these devices generally run somewhat hotter than normally experienced in real-life service use to provide some additional test acceleration, but without inducing undesirable thermal artifacts.

Likewise, humidity levels are representative of typical service environment, with specimen water sprays available, if appropriate, (capabilities vary with instrument model) to simulate moisture condensation or precipitation.

Laboratory Exposure Chambers Since the mid-1950's exposure devices simulate full-spectrum terrestrial solar radiation (that which is filtered by the atmosphere and reaches the earth's surface) using optically filtered xenon arc gas discharge lamps. This is currently the "gold standard" in solar simulation technology and used extensively in industries such as plastics, paints and coatings, apparel and industrial textiles, automotive exterior and interior components, pharmaceuticals, building products, foods & beverages, personal care products, colorants and additives, solar energy, etc. It's rare to find a product or material that has not undergone lightfastness or weather durability testing in this way.

Atlas Xenon Instruments for CE Durability Testing

To meet the demands of various industries, Atlas produces three related lines of xenon-arc based weathering/lightfastness exposure instruments: The Ci-Series of Weather-Ometers, the Xenotest series of instruments, and the SUNTEST line. Depending on the specific instrument, these will vary by:

- Test specimen size, shape and capacity
- Stress parameters controlled and performance envelope
- Chamber size and geometry
- Spectral simulation: outdoor or glass-filtered solar radiation, artificial Store Light
- Light/Dark, temperature and humidity cycling, additional cooling, and other features

All models feature automatic irradiance control, that is the ability to maintain a programmed light intensity (irradiance) setpoint(s), and various lamp optical filters to tailor the radiation spectrum that specimens are exposed to.

For CE testing, the Ci-Series is the most widely used globally. The line consists of the Ci3000, Ci4000, Ci5000 and the newest instrument, the Ci4400. All feature a single high powered water-cooled optically filtered xenon arc lamp, a rotating test specimen rack for maximum exposure uniformity and water sprays for test cycles using them. All models control test chamber air (ambient), specimen surface temperature (via a black panel reference thermometer), relative humidity, and allow light/dark cycles at various temperature and humidity conditions. The Ci-3000 and Ci4000 are in wide use for CE testing worldwide, and specified in many CE OEM test methods.

The Xentotest line is like the Ci Series but uses a lower power air-cooled xenon arc source and is used where sample sizes are smaller and high sample capacity is not required. The XT-440 is the model preferred for CE testing.

The SUNTEST line also uses air-cooled xenon arc lamps but configured for a horizontal “flat tray”. The SUNTEST XXL+ (shown below can accept larger or more three-dimensional test specimen geometries.

Large Product Exposures

In addition to the standard models of instruments Atlas produces and uses in our commercial laboratory testing services, Atlas provides custom systems for large area solar simulation, or where wider climate variations are required.

Luminaires based on special solar-simulating metal halide lamps and electronic control systems may be incorporated into specialty environmental climate chambers. Solar/Environmental chamber testing is performed as a commercial lab service by Atlas at our Solar Test Center at the Arizona exposure site.

These lighting systems can be scaled up to extremely large systems for either solar thermal load or solar radiation weathering purposes, as shown in the U.S. Air Force photo of an F-35 Joint Strike Fighter under solar heat load test.

Testing Methodologies

The selection of test conditions will be covered in the next section, but regardless of the test method selected, the question of how long to test is an important one, and highly dependent upon the purpose of the test. There are two common approaches.

Test to Failure Approach

In the “test to failure” (TTF) approach the accelerated test(s) is run until an unacceptable level(s) of degradation is attained, then that data is used to estimate a useable service life under either typical and/or worst-case usage conditions. This testing is frequently used to help determine or support warranty statements as well as uncover potential safety issues and is mostly Clearly, products designed for either more severe or longer service life, such as outdoor televisions and display technologies, will require higher durability than products likely to have either short lifetime (e.g., a few years or less), are used only occasionally outdoors, or both.

Qualification v. Acceptance Testing

The **Qualification Test Protocol** is usually quite different from the Acceptance Test Protocol.

The Qualification Test is more comprehensive than the ATP and is performed once to qualify the design.

The QTP is defined in the contract and, for example, includes environmental testing.

The ATP is a production test performed on each item to show it meets the performance specification, and may be required for each batch or lot.

It should be noted that the testing should include stresses likely to be encountered during the product lifecycle. Many CE products, for example see very high heat and humidity conditions during containerized shipment that would not be encountered under normal service use, and this may require testing under both transport and end-use service conditions to identify potential issues.

Qualification Test Approach

In the screening test approach one or more tests are run to pre-determined duration endpoints. If any degradation is within acceptable limits, the material, component or product “passes”. These durations can be based on:

- Prior experience with the same or similar materials in both testing and service use
- An approximation of test duration to attain a test “equivalent” to some reasonable service expectation

The latter approach is most common, the choice of test duration accounting for the expected product usage duty cycle. Smartphones, for example, would not typically be exposed to full direct sunlight from dawn to dusk every day, but a boating fish locator or outdoor entertainment system might be.

Among the three main environmental stress factors of heat, light and moisture, it is not usually known what effect each has on the degradation mode. Nor is the exact degradation mechanism usually known in advance. However, although useful for mitigation purposes, it is not necessary to know the degradation mechanism provided the test conditions are realistic in terms of the end use conditions, allowing sufficient margin for error.

Test Standards and Methods

There are no international standard test methods specifically for consumer electronics durability testing. That is not to say that there are not standards which provide either general guidance or specific test parameters. A few of the approximately 1500 international weathering standards that include a test for lightfastness / weathering resistance are shown in **Table 1** below.

In terms of consumer electronic devices, we can define several broad categories of durability requirements based on the expected in-service exposure:

- Ruggedized” products designed to be continuously exposed outdoors in various climates, such as outdoor entertainment or security systems

- Products intended for frequent outdoor use, which will likely to be occasionally exposed to elements such as rain, including fitness trackers, personal GPS, cameras, UAV control consoles, etc.
- Devices which may be used outdoors but generally protected from harsh conditions, such as smartphones, tablets, laptop computers
- Products normally not exposed to harsh outdoor conditions, but which may be left in vehicles for extended periods
- Products used almost exclusively indoors or in protected environments, but which may be exposed to sunlight through open windows or to window-glass filtered daylight.
- Devices likely to only be exposed to normally conditioned indoor spaces and only artificial lighting with no daylighting.

Common international test standards for durability testing

ISO 16474-1:2013 - *Paints and varnishes – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 16474-2:2013 - *Paints and varnishes – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ASTM G151:2010 - *Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources*

ASTM G155:2013 - *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*

ASTM D2565:1999 (reapproved 2008) - *Standard Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications*

ASTM D7869:2013 - *Standard Practice for Xenon Arc Exposure Test with Enhanced Light and*

IEC 60068-2-5 Electrical engineering - Environmental testing - Part 2: Tests; test Sa: Simulated solar radiation at ground level

IEC 60068-2-9 Electrical engineering - Basic environmental testing procedures - Part 2-9: Tests - Guidance for solar radiation testing

DIN EN 60512-11 Connectors for electronic equipment - Tests and measurements: Climatic tests

ISO 15314:2004 - *Plastics - Methods for marine exposure*

ISO 11997-1:2005 - *Paints and varnishes - Determination of resistance to cyclic corrosion conditions - Part 1: Wet (salt fog)/dry/humidity*

ISO 11997-2:2013 - *Paints and varnishes - Determination of resistance to cyclic corrosion conditions - Part 2: Wet (salt fog)/dry/humidity/UV light*

ASTM D 5894:2010 - *Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)*

MIL-STD-810G Method 505.5 (2008) - *Solar Radiation (Sunshine) Procedure II – Steady State Test*

DIN 75220:1992 - *Ageing of automotive components in solar simulation units*

Table 1. Examples of international test standards which may have applicability to consumer electronics material and product testing.

Many engineering sectors use durability testing (environmental testing) as a regular part of product design and validation, including the electronics industry, medical and healthcare sectors, and defense, automotive and aerospace industries.

However, most of these standards and their options contain conditions which may not be appropriate for consumer electronics devices and the way they are used and exposed to service environments. As a result, most CE companies performing durability tests have either modified these methods, use or modify Atlas' test method recommendations (below), or created their own test methods and specifications, often in consultation with Atlas.

Atlas Test Method Recommendations

Based on over 100 years of practical experience, Atlas' has created several methods for xenon arc testing consumer electronic devices **(Tables 2-4)**. These are based on the various typical service exposure conditions which may for CE devices and the performance capabilities of the different Atlas xenon instrument lines. These may be used as-is or modified, as appropriate.

To put exposure test times into some perspective, **Table 2** Test Methods for Ci-Series instruments includes general guidance regarding the approximate "equivalent" radiant energy (UV) exposures for 200, 400 and 1,000-hour exposures with the following caveats:

- These are approximate based only on *estimated* average UV radiant energy exposure (dose) only.
- Outdoor direct weathering and window glass filtered sunlight comparisons are based on an at-latitude tilt angle (to optimize direct beam solar radiation) south facing exposure racks at Atlas' Phoenix and Miami area outdoor exposure test sites.
- Under glass exposures are based on conventional single strength (2.8-3.0mm) soda lime float glass.
- Automotive interior estimates are based on the top of the instrument panel location, south facing Miami or Phoenix; other cabin locations will vary.

Table 2 consists of several possible test cycles for various conditions for the Ci Series instruments. There are alternative methods for Xenotest and SUNTEST instruments in **Tables 2 & 3**.

The Atlas recommended test cycles are as follows:

- **Daylight Test 1-Sun**: A continuous outdoor daylight exposure at established "1-Sun" levels under constant temperature and humidity, no water sprays. This is suitable for primarily outdoor exposures where products remain dry.

- **Daylight Test 2-Sun:** Similar to the above test, but a 2X sunlight intensity for higher test acceleration. This cycle provides a longer outdoor equivalent for a given test time duration than the 1-Sun test.

- **Outdoor Weathering 1-Sun**: A wet/dry alternating continuous daylight exposure with periodic water sprays and high humidity. This is a true weathering test when products will be exposed outdoors and see wet time.

- **Indoor Window Glass Filtered Daylight**: Continuous light at controlled temperature and humidity, simulates indoor window filtered daylight. This is for products that will be exposed indoors but near daylit windows, doors or skylights.

- **Automotive Interior Semi-Tropical Humid Climate:** A light/dark cycle at elevated temperature and humidity, automotive glazing filtered sunlight. Designed for products mounted or often left in parked vehicles in hot/humid conditions.

- **General Automotive Interior:** A continuous light test with lower humidity. Designed for products often left in vehicle cabins in temperate climates

- **MIL STD 810G Method 505.5 Procedure 2 Actinic Radiation:** Military standard UV/Solar test for photodegradation and solar thermal load. Designed to test the effects of UV and solar load on material and product degradation.

Table 2 Ci Series Weather-Ometer® Consumer Electronic Test Methods

Parameter	Daylight Test "1-Sun"	Daylight Test "2-Sun"	Outdoor Weathering "1-Sun"	Indoor Window Glass Filtered Daylight	Automotive Interior Semi-Tropical Humid Climate	General Automotive Interior	MIL STD 810G Method 505.5 Procedure 2 Actinic Solar Radiation
Instrument Type	Ci Series rotating rack Ci3000, Ci4000, Ci4400, Ci5000	Ci Series rotating rack Ci4000, Ci4400, Ci5000	Ci Series rotating rack Ci3000, Ci4000, Ci4400, Ci5000	Ci Series rotating rack Ci3000, Ci4000, Ci4400, Ci5000	Ci Series rotating rack Ci3000, Ci4000, Ci4400, Ci5000	Ci Series rotating rack Ci3000, Ci4000, Ci4400, Ci5000	Ci Series rotating rack Ci3000, Ci4000, Ci4400, Ci5000
200 hour exposure	~ 1 ½ months Phoenix	~ 3 months Phoenix	~ 1 ¾ months Miami	~ 1 ¾ months Phoenix	~ 1.5 months Miami	~ 3 months Phoenix	~ 1 ½ months Phoenix
400 hour exposure	~ 3 months Phoenix	~ 6 months Phoenix	~ 2 months Miami	~ 3 ½ months Phoenix	~ 3 months Miami	~ 6 months Phoenix	~ 2 ¾ months Phoenix
1,000 hour exposure	~ 7 ¾ months Phoenix	~ 15 months Phoenix	~ 10 months Miami	~ 9months Phoenix	~ 8 months Miami	~ 14.5 months Phoenix	~ 7 months Phoenix
Filter Combination	*Inner:* Right Light *Outer:* CIRA/Quartz	*Inner:* Right Light *Outer:* CIRA/Quartz	*Inner:* Right Light *Outer:* CIRA/Quartz	*Inner:* Borosilicate - Type S *Outer:* Soda Lime	*Inner*: Quartz *Outer:* Borosilicate Type S *Filter Lantern:* Schott SF5 335nm Long Pass	*Inner:* Borosilicate Type S *Outer:* Soda Lime	*Inner:* Right Light *Outer:* CIRA/Quartz
Irradiance	0.60 W/m^2 • 340nm 1.1 W/m^2 • 420nm 60 W/m^2 • 300-400nm	1.1 W/m^2 • 340nm 2.1 W/m^2 • 420nm 120 W/m^2 • 300-400nm	0.60 W/m^2 • 340nm 1.1 W/m^2 • 420nm 60 W/m^2 • 300-400nm	1.1 W/m^2 • 420nm 50 W/m^2 • 300-400nm	1.1 W/m2 • 420nm	1.8W/m2 • 420nm 80 W/m2 • 300-400nm	0.68 W/m^2 • 340nm 69 W/m^2 • 300-400nm
Black Panel Temperature	55°C	73°C	55°C	55°C	89°C Light / 38°C Dark	89°C	Adjust to maintain chamber temp.
Chamber Temperature	35°C	43°C	35°C	35°C	62°C Light / 38°C Dark	50°C	Cycle A1 Worldwide Hot Dry 49 ± 2 °C Cycle A2 Basic Hot 43 ± 2 °C Both Light & Dark Cycles
Relative Humidity	70%	50%	70%	60%	50% Light / 95% Dark	50%	Not required/unspecified
Water Spray (Front)	None	None	Intermittent	None	None	None	None
Cycle	Continuous Light	Continuous Light	Light: 102 min Light + Water Spray: 18 min	Continuous Light	228 min Light 60 min Dark	Continuous Light	20h Light 4h Dark Recommended: 56 cycles

Table 3 Xenotest® Consumer Electronic Test Methods

Parameter	Daylight Test "1-Sun"	Daylight Test "2-Sun"	Outdoor Weathering "1-Sun"	Indoor Window Glass Filtered Daylight	Automotive Interior Semi-Tropical Humid Climate	General Automotive Interior	MIL STD 810G Method 505.5 Procedure 2 Actinic Solar Radiation
Instrument Type	Xenotest rotating rack 440, Beta+	Xenotest rotating rack 440, Beta+	Xenotest rotating rack 440, Beta+	Xenotest rotating rack 440, Beta+		Xenotest rotating rack 440, Beta+	
Optical Filter	Daylight (440); XENOCHROME 300 (Beta+, Alpha+)	Daylight (440); XENOCHROME 300 (Beta+, Alpha+)	Daylight (440); XENOCHROME 300 (Beta+)	XENOCHROME 320		XENOCHROME 320 IR (440); XENOCHROME 320 (Beta+, Alpha+)	
Irradiance	60 W/m^2 • 300-400nm	120 W/m^2 • 300-400nm	60 W/m^2 • 300-400nm	50 W/m^2 • 300-400nm		80W/m2 • 300-400nm	
Black Standard Temperature	60°C	83°C	60°C	60°C		100°C "Hot Lightfastness"	
Chamber Temperature	35°C	43°C	35°C	35°C		65°C	
Relative Humidity	70%	50%	70%	60%		50%	
Water Spray (Front)	None	None	Intermittent	None		None	
Cycle	Continuous Light	Continuous Light	Light: 102 min Light + Water Spray: 18 min	Continuous Light		Continuous Light	

Table 4 SUNTEST® Consumer Electronic Test Methods

Parameter	Daylight Test "1-Sun"	Daylight Test "2-Sun"	Outdoor Weathering "1-Sun"	Indoor Window Glass Filtered Daylight	Automotive Interior Semi-Tropical Humid Climate	General Automotive Interior	MIL STD 810G Method 505.5 Procedure 2 Actinic Solar Radiation
Instrument Type	SUNTEST Flatbed XXL+		SUNTEST Flatbed XXL+	SUNTEST Flatbed XXL+		SUNTEST Flatbed XXL+	
Filter Combination	Daylight		Daylight	Window Glass		Window Glass "Hot Lightfastness"	
Irradiance	60 W/m² • 300-400nm		60 W/m² • 300-400nm	50 W/m² • 300-400nm		60 W/m2 • 300-400nm	
Black Standard Temperature	62°C		62°C	62°C		100°C	
Chamber Temperature	35°C		35°C	35°C		65°C	
Relative Humidity	70%		70%	60%		50%	
Water Spray (Front)	None		Intermittent	None		None	
Cycle	Continuous Light		Light: 102 min Light + Water Spray: 18 min	Continuous Light		Continuous Light	

AMOLED Display Testing

One final note regarding OLED display testing, such as used on high end smartphones. Currently, production of AMOLED displays is rapidly increasing, with new production plants and manufacturers coming online within the next several years. Due to the current comparatively low yields on these displays, and a known UV sensitivity of the organic LED chemicals, especially the blue pixel, almost all smartphone OLED screens are being batch tested, usually to conditions similar to **Daylight Test 2-Sun** at the production facilities prior to product acceptance. The Atlas Models Ci3000, Ci4000 and Ci4400 are frequently specified in OEM test requirements for this testing.

Corrosion Testing

For products which may be exposed to corrosive salt air, corrosion testing using international standard corrosion chambers and test methods is typically used. These may be either steady-state salt fog (a.k.a. salt spray) and condensing humidity tests or various wet/dry cyclic tests. Atlas SF Series corrosion chambers perform common steady-state tests such as ASTM B117 and ISO 9227, while BCX and CCX models are also capable of basic and the more complex automotive-type cyclic wet/dry corrosion tests. Atlas also performs corrosion testing as a lab service.

Summary

Environmental durability is a specialized subset of reliability. It concerns itself with characterizing unacceptable changes to a material or product that result from normal in-service exposure to the elements of light, heat and moisture. Unlike torture tests, or highly accelerated stress tests for sudden, catastrophic failure, durability testing targets the longer term “wear out” period under near-normal, but still somewhat accelerated, conditions. The combination of light, with the appropriate spectral distribution for the end-use environment, as well as heat and moisture, where appropriate, are simultaneously applied in special test chambers called laboratory artificial accelerated weathering instruments.

Material property changes resulting from chemical and physical degradation from environmental exposure do not need to prevent the product from working to be considered a failure. “Unacceptable” is a perception held by the owner or user, and this includes appearance properties. Yellowed or faded plastic on an expensive device can be just as unacceptable as intermittent electrical performance. In other words, it affects quality and brand reputation.

Durability tests simulate the end use environments to which products will be exposed, when being used or not, which can result in material degradation, and are extensively used in many industries. Today, major consumer electronics OEMs with well-established quality and reliability programs use Atlas equipment and services throughout their supply chains to avoid the risk of product failures. This included not only new product verification testing, but also for ongoing acceptance testing to prevent supply chain issues of bad material or process changes that can result in field failures.

By incorporating environmental durability testing into your quality program, you will help avoid risk and unhappy customers. Please contact Atlas for information on our testing products and services.

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About the Author

After graduating with degrees in electronics engineering and analytical chemistry, Allen spend the first 19 years of his career with various analytical instrument companies as a technology specialist in gas, liquid and ion chromatography, electrochemistry, supercritical fluids, polymer molecular weight characterization, spectroscopy, spectrometry and other analytical specialties.

He joined Atlas in 1993 and has served in several capacities. He currently is Global Weathering Applications Manager as well as Senior Consultant – Weathering Science and Product Manager – Corrosion and Flammability.