Environmental tests to prove/improve reliability of solar panels and related products
Environmental test chamber considerations for PV reliability & certification testing

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INTRODUCTION

The time is now for clean, renewable energy technologies. Favorable government tax credits, a decreased dependency upon oil, and the need to stimulate the economy are just three of the planets that have aligned, favoring the expansion of technologies that harness the sun's energy. Manufacturers of Solar Photovoltaic (PV) modules and panels strive to improve product efficiency, reliability and cost effectiveness. To this end, it is necessary to perform requisite testing to insure products are capable of withstanding the environments they are likely to encounter during their intended lifetime.

WHAT IS THE PURPOSE OF SOLAR PANEL TESTING?

The overriding objective for testing PV products is to enhance the durability, longevity, and performance of photovoltaic modules and solar panels. When placed in service these products are exposed to searing heat, sub zero freezing cold, and drenching high humidity. These outdoor environmental conditions can be tortuous over the lifetime of a product, and are the culprits for triggering many of the most common failure mechanisms.

Tests are performed at various stages and for a variety of purposes; at the R&D phase to prove out design robustness, accelerated testing to predict lifetime or meantime between failures, for winning safety and certification marks required to sell and install PV products, and in production for sample lot reliability verification.

Currently, the life expectancy for solar products has increased to 25 years. While only a short time ago in the 1990's warranties were transitioning from 10 years to 20 years. Substantial safety margins are typically expected to insure that warranties do not become a concern. Solar modules and panels have been tested out to twice the life of the warranty to insure the durability of their products. One approach for Test-To-Failure suggests increasing the qualification test duration protocol to 15 repetitions to determine if the design is able to survive such extreme amounts of stress. In this example, thermal cycles are increased from 200 to 3,000 and damp heat duration is increased from 1,000 hours to 15,000 hours. Solar products are commonly tested all the way to failure to establish baseline criteria for expected product life.

As if solar companies are not already busy enough testing the reliability of their solar panels and products, they are also required to have these products certified by an independent third party testing organization.

WHAT ARE THE MOST COMMON SOLAR PANEL TEST SPECIFICATIONS?

Design qualification and type approval guiding doctrines include IEC 61215 "Crystalline Silicon Terrestrial Photovoltaic (PV) Modules" and IEC 61646 "Thin Film Terrestrial Photovoltaic (PV) Modules". Design qualification testing is a set of well-defined accelerated stress tests with strict pass/fail criteria. The goal is to accelerate the same failure mechanisms observed in the field in a reasonably short period of time. Accelerated qualification testing is carried out on crystalline silicon technologies per IEC 61215.

International Electrotechnical Commision (IEC)

Test Specification	Test Name	Test Specification Description
IEC 60068-2-78	Environmental Testing - Part 2-78: Tests - Test 2-78: Body Cab: Damp Heat, Steady State	Establishes a test method for determining the suitability of electrotechnical products, components or equipment for use under conditions of high humidity by observing the effect of high humidity at constant temperature without condensation on the product over a prescribed period of time.
IEC 61215	Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval	Provides requirements for design qualifications and type approval for crystalline silicon terrestrial photovoltaic modules for long-term use in general open-air climates. Includes Thermal Cycling, Humidity Freeze and Damp Heat tests.
IEC 61646	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval	Sets requirements for the design qualification and type approval of terrestrial thin-film photovoltaic modules suitable for long-term operation in open-air climates. Includes Thermal Cycling, Humidity Freeze and Damp Heat Tests.
IEC 62108	Concentrator Photovoltaic (CPV) Modules and Assemblies - Design Qualification and Type Approval	Specifies the minimum requirements for the design qualification and type approval of concentrator photovoltaic modules and assemblies suitable for long-term operation in general open-air climates. Includes Thermal Cycling, Damp Heat and Humidity Freeze Tests.
IEC 61730	Photovoltaic (PV) module safety qualification	Describes the testing requirements for photovoltaic (PV) modules in order to provide safe electrical and mechanical operation during their expected lifetime. Tests include polymeric materials, internal wiring, connections and bonding and grounding testing.

***Table 1:** IEC test specification details for solar panel testing*

UL 1703 “Standard for Flat-Plate PV Modules and Panels” calls for test conditions that simulate a generation’s worth of weather within 45 days. Test Engineers put solar products through multiple thermal cycles, from -40°C to +90°C. They also verify safety under various humidity levels. Typical testing must also comply with the safety requirements specified in IEC 61730-1/2.

As seen in Table 1, the IEC 61215 and 61646 are design qualification certification standards while the UL 1703 and IEC 61730 safety certification is a regulatory driven requirement.
The purpose of the thermal cycling test is to determine the ability of the module to withstand thermal mismatch, fatigue and other stresses caused by repeated changes in temperature. Within the field of PV module and panel testing, thermal cycling and damp heat stresses have been reported by laboratories performing standard qualification tests to cause the highest number of failures.

Majority of failures in the field relates to corrosion and cell or interconnect breaks (Table 2). By strenuously testing the panels and observing the types of conditions these failures occur at, laboratories can accurately set warranty standards and ensure the quality of the panels will be able to withstand these types of failures.

1,000 hours of damp heat testing at 85°C & 85%RH equates to 20 years of outdoor exposure in Miami, Florida. Thermal cycle testing between -40°C and +85°C for 200 cycles has become the de facto industry standard. These tests are specified with 10 minute minimum dwell times at the upper and lower temperatures and temperature transitions between -40°C and +85°C not to exceed 100°C/hr (1.67°C/min).

Manufacturers typically offer warranties on module power based on 1% per year degradation. In the case of a 20 year warranty, the manufacturer will replace a module whose power output drops below 80% of the initial power.

Types of Failures	% of Total Failures
Corrosion	45.3
Cell or Interconnect Break	40.7
Output Lead Problem	3.9
Junction Box Problem	3.6
Delamination	3.4
Overheated wires, diodes or terminal strip	1.5
Mechanical Damage	1.4
Defective Bypass Diodes	0.2

***Table 2:** Types of field failures observed by BP Solar*

WHAT EQUIPMENT IS NEEDED TO PERFORM THESE TESTS?

The total solar test system is comprised of three major components: a test chamber capable of accurately reproducing the environments (temperature humidity conditions) required by the test specification; a fixture capable of supporting the panels being tested inside the chamber; and functional product test instrumentation to apply appropriate current, voltage and thermocouple monitoring.

1. THE TEST CHAMBER

The chamber must have sufficient internal capacity to contain the specified number of thin or thick solar panels. Common upright environmental chamber workspace sizes range from 4’ wide x 4’ high x 4’ to 6’ deep (1.2 m wide x 1.2m high x 1.2 to 1.8m high). In chambers of this style, it is common to load 10 to 20 panels inside depending upon their thickness. If panels approach 7’ to 8’ deep (2.1m to 2.4m deep), the chamber will likely take the shape of a small walk-in, with the capacity of testing 60 panels or more.

Airflow in the chamber is crucial to performance and repeatability. There must be sufficient airflow around all surfaces of the solar panels to insure proper uniformity. It is important that the airflow distribution within the chamber is consistent and dead spots are eliminated.

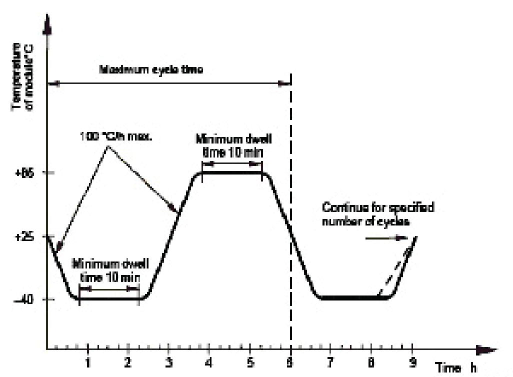

***Figure 1:** Thermal cycling test*

IEC and UL solar test specifications call for test conditions as low as -40°C. It is essential the chamber be capable of providing substantial capacity at these low temperatures. To accomplish this, it is advantageous to specify a chamber that uses a cascade refrigeration system. Cascade refrigeration has an ultimate low temperature of -73°C, providing high capacity cooling through the working range. On the upper end of the temperature range, the specifications require +85°C. This temperature is easily accommodated in the solid or welded chamber construction, but is not recommended for chambers of the prefabricated walk-in panel variety, especially when high humidity levels with elevated vapor pressure are required.

The IEC 61215 Humidity Freeze Test includes a very challenging condition where humidity must be controlled during temperature transition. This requires special design consideration. The refrigeration and humidity systems need to be sized and controlled via a sophisticated software algorithm.

Damp heat tests lasting 1,000 hours and sometimes as long as 2,000 hours or more require a chamber

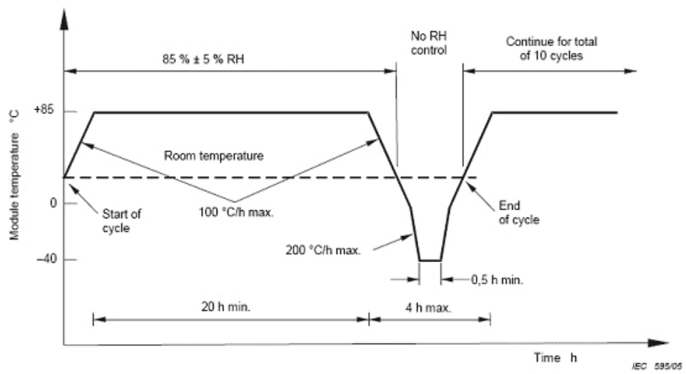

Figure 2: *Humidity-freeze cycle*

capable of running maintenance free 24/7 for a month or more at a time. Reliability is critical to the success of the test that these chambers run maintenance and failure free for extended test periods. Reliable sensors, water supply, and adherence to proper preventive maintenance all factor into a chamber that will perform for the long haul.

Some loading applications are better served by a chamber with internal dimensions that offer more depth than height. With this configuration, longer panels can be more easily handled and loaded into the chamber in a horizontal “landscape” orientation rather than the vertical “portrait” orientation. This may enter into the selection of the chamber that best fits the application. Handling a larger solar panel and attempting to load it in the vertical orientation can be top heavy and cumbersome.

Environmental test chamber with fixtures and solar panels, ready for testing

2. THE MOUNTING FIXTURE

Whether tests are carried out on thicker Crystalline Silicon PV modules and panels or thin film panels of the Cadmium Telluride (CdTe) and Copper Indium Gallium diSelenide (CIGS) variety, the test set-up must incorporate a means to support the products under test to provide proper air distribution. The fixture or support mechanism must withstand the extremes of the environment. Materials of construction must be robust yet lightweight to minimize thermal load and conductivity. It is also desirable to thermally isolate the mounting fixture from the panels being tested. Finally, the products must be able to be easily loaded into and removed from the support fixture. In certain situations, it is very helpful to have a fixture with flexibility and adjustability to accommodate variable loading of panels with various size and configuration. Wear points within the fixturing solution must be durable yet easy to replace without compromising the integrity of the entire framework. In many applications, it is desirable to permanently mount the panel support fixture to the interior walls of the environmental test chamber. When done in this fashion, each solar panel to be tested is individually loaded into the fixture chassis. Another configuration involves a rolling cart, which is loaded with panels outside the chamber and slid into position. This concept works well in production settings where throughput is a critical concern. One cart can be pre-loaded with panels while the other cart is inside the chamber. A quick swap-out can save time and improve productivity.

3. TEST INSTRUMENTS & DATA ACQUISITION

New IEC 61215 standards require application of peak power current during thermal cycling when the module temperature is above 25°C. One way to accomplish this power performance testing is with a power supply programmed to provide current and voltage levels to the PV products under test. These levels are similar to those the operating PV products are capable of producing when they operate in field installations. Rather than the products developing power from the sun, this power is being sent to them via the power supply.

In most cases, it is desirable to monitor and log temperature data on each solar panel or device. This multi channel data acquisition function can be accomplished directly through the chamber control system interface on the more sophisticated chambers.

SUMMARY

Solar Photovoltaic (PV) modules and panels are growing in popularity among consumers due to emerging renewable energy trends. The near future holds the ability to power vehicles, cell phones, laptops, lamps and aircrafts with solar panels. In order to effectively power these devices, the solar panel must be able to withstand their likely environmental surroundings.

To test the panels against their environment, many considerations need to be made before test equipment is selected. First and foremost, the types of tests need to be designed based on test standards such as IEC 61215, IEC 61646, IEC 61731 and UL 1703. Solar panel dimensions also need to be considered. The chamber needs to accommodate the quantity of panels being tested, as well as the loading technique to optimize efficiency. One must decide whether or not the panels will be powered on during testing, determine the level and sophistication of functional testing, and the data measurement and acquisition needs such as temperature, voltage, and current.

The versatility of these panels to power a wide range of devices means that determining testing methods and proper test equipment is a critical phase in manufacturing these products. Carefully crafting proper test procedures will help ensure a long product lifecycle.

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