ESPEC Solar Application Guide

Review of the IEC 61215 and 61646 methods

ESPEC NORTH AMERICA, INC.

Contents

Introduction:

There are two major standards for environmental testing of photovoltaic (PV) solar panels published by International Electrotechnical Commission (IEC), www.iec.ch. These test specifications are:

- 61215 for PV modules made from silicon crystal
- 61646 for PV modules made with thin-film polymers

In addition, Underwriter's Laboratories has published their own version of these tests:

- UL-1703 for Flat-Plate Photovoltaic Modules and Panels

This application guide will discuss the issues in complying with these test methods from the perspective of an environmental test chamber manufacturer and their users, as well as outlining suggested program profiles for these tests. By understanding these tests, chamber purchase and utility savings can result, and potentially quicker results.

The three temperature & humidity tests in these specifications are essentially the same. The environmental tests discussed in this guide are:

- 10.11 Thermal Cycle Test
  Requires temperature cycling between 85°C and -40°C, 50 or 200 times.
- 10.12 Humidity Freeze Test
  Cycling between hot/humid 85°C/85%RH and subfreezing -40°C ten times, with extended soaks at 85/85.
- 10.13 Damp Heat Test
  A long term, 1,000 hour, test at 85°C/85%.

Section 1: Technical Issue with the Standards

Like most test specifications, the written document can leave certain details confusing or erroneous once applied in the field. This section is to help explain the most confusing issue with the UL & IEC test standards, and offer clarification based on our experience.

Air-temperature versus Module-temperature

While not explicitly stated, these test standards are judging temperature cycling rates and soak period based on ***module*** temperature, not ***air*** temperature. This requirement is identified only in the graphs in the IEC standards, calling the Y-axis ‘temperature of module °C‘.

The UL specification is more explicit, calling for “a transition in the test chamber temperature”, and that dwells be “until the module or panel attains a temperature within ±2 °C of the chamber temperature”. Their graphs also show the expected lag of the module temperature.

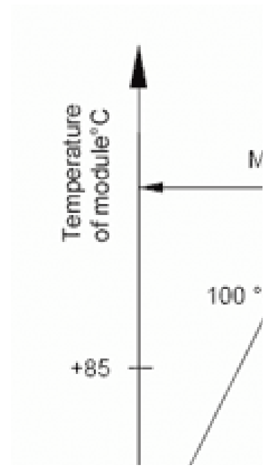
Specifying module temperature in these specifications adds complexity to compliance. Although chamber manufacturers offer controllers that work based on the sample temperature and not ‘supply air’ as primary input, performance and control behavior is different.

While a controller can be set to Product Temperature Control (PTC), this means the success of the test is much more dependent on the how the chamber is loaded. While it may be obvious that the location of the sensor the controller uses as an input will determine the resulting rate, one should also be concerned about differences from sample to sample. A ‘representative’ sample will need to be selected.

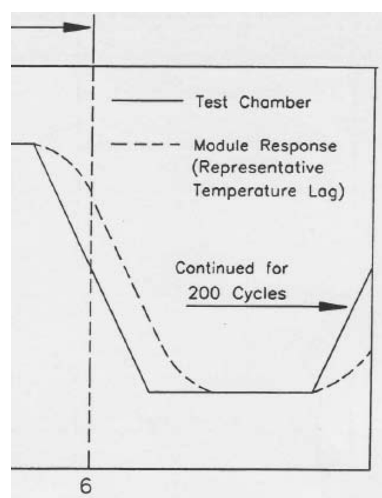
Note also that PTC may not be directly coupled to the sample, but indirectly via the supply air. This introduces some delta and latency issues in assuring the specified transitions and soaks are complied with.

PTC is especially challenging to apply because the IEC specifications call out maximum change rates. If the controller attempts to slow down the cooling to avoid exceeding the maximum, the loss of momentum can be hard to recover. Those attempting to control temperature following a ‘linear’ profile will require a larger refrigeration system.

The UL specification is different because it identifies that the temperature transitions are of the chamber air temperature, making control of the ramping easier, and likely requiring a less powerful chamber.



In the IEC specifications, this label of the Y-axis is the only specific confirmation that leads one to assume all change rate maximums regards the ‘temperature of module’.



The UL specification distinguishes the difference between the ‘Test Chamber’ and the ‘Module Response’.

Using Module-temperature

ESPEC recommends careful characterization of the test load and adjustments to the programmed test profile accordingly for all applications where PTC is being used. In cases where users choose to control the chamber by air temperature and not module temperature, characterization is essential to comply with the specifications for module soak times.

Since there is a significant difference in the minimum and maximum module ramp rates (especially for 10.11), the user also has options as to how powerful a chamber they will buy, and how much load they will test at a time. (See section about selecting chambers.)

TIP: One consideration in characterization and developing a test profile is deciding whether temperature change steps will be step-ramps or linear-controlled.

- A step-ramp is when the set-point is suddenly changed to the final desired temperature, then allow the chamber to 'catch-up' as quickly as possible. While fast change rates are discouraged by these specifications, use of step-ramps may be needed to ensure maximum heating and cooling capacity is employed by less-powerful chambers.

- A linear-controlled step incrementally changes the set-point, attempting to maintain a linear ramp to the desired setpoint. This type of ramping is helpful in ensuring a specific change rate is achieved. However, the fluctuations in heat/cool demand can make the chamber fall behind the desired set-point unless the system is oversized.

Section 2: Selecting the right chamber(s)

While ESPEC can anticipate certain size and performance requirements for testing PV modules, ultimately, you, as the module manufacturer needs to decide the needed features for your application. Factors such as desired throughput, testing procedures, floor-space, and budget will affect the final selection.

TIP 1: Get a separate chamber just for damp heat test
All three of the IEC 61215 & 61646 environmental tests ESPEC chambers are used for can be done in the same test chamber. It may be better, however, to consider multiple chambers to save time and electricity due to the lengths of the tests:

- The damp heat test is six weeks long.
- The damp heat test requires only minimal refrigeration to help ensure steady control, and for cool-down after completion.

TIP 2: Aiming for the minimum change rates of the tests will save you money and utilities.
Because the change rates in the specifications are flexible, you have a choice of selecting a slower system to save cost and utilities, or a faster system to shorten testing time.

- The temperature cycling test may last up to seven weeks.

TIP 3: If buying a separate chamber for the temperature cycling test, add humidity control anyway.
The temperature change rates for the temperature-cycling and humidity-freeze tests are similar, so the heating/cooling systems required would be the same. A specialized chamber without humidity control can be purchased for the temperature cycling test, however the incremental cost of a humidity system is reasonable, making for an acceptable expense for added flexibility in testing.

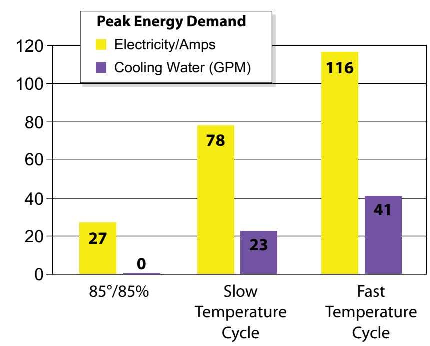
TIP 4: Be prepared when requesting a chamber quotation.
In order to quote, ESPEC will need to know the desired change rates and test load, so that we can calculate the heat and refrigeration required. Specifically, the following information would be needed to evaluate and price your requirement:

- Chamber interior space required.
- Total mass of modules and supporting racks to be tested.
- Desired heat & cooling rates (i.e. minimum or maximum rates allowed by IEC).

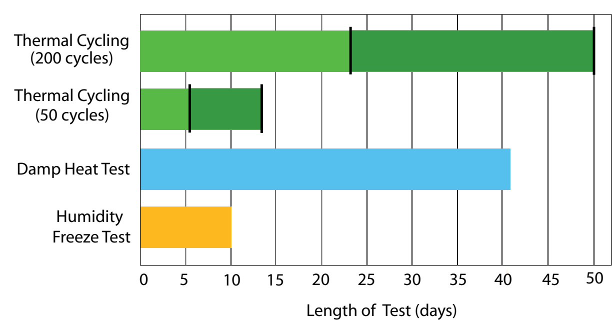
TIP 5: Plan for utility requirements
The long-term cost of an environmental chamber is driven by the electricity and cooling water it demands. As stated earlier, decisions about change-rates and ramp-control influences the size of the refrigeration and heating needed. Larger refrigeration and heating systems need more power and cooling water.

The chart below shows peak utility demand for the same chamber with three different refrigeration systems to illustrate the differences. Actual operating demand will vary based on the conditions being operated.

Solid walk-in chambers like this one are commonly selected for full-size solar panel testing.



Chamber utility requirements can vary depending on the tests and desired performance. This chart shows different solid walk-in chamber peak demand.



The IEC and UL tests can take a significant amount of time to complete. Purchase of multiple chambers may be beneficial to save time.

Section 3: Test Methods Review

- 10.11 Thermal Cycle Test.
- 10.12 Humidity Freeze Test
- 10.13 Damp Heat Test

ESPEC Review of 10.11 Thermal Cycle Test (UL 35)

This test should be the one most closely reviewed before hiring a lab or buying a test chamber. The variation in change rates allowed can make a significant difference in how long the test needs to run, as well as how powerful your test chamber needs to be.

The test specifies a maximum time for each cycle at 6 hours, but can be completed in as little as 2.8 hours. With up to 200 cycles required, almost a month of testing time is saved if done as quickly as allowed.

The alternative is to run the test at the slower rate, which will allow you to purchase a less costly chamber, and use less utilities.

The following chart is from the IEC specification, and has been overlaid with red numbers indicating 'steps' as should be programmed into a test chamber. Note: The UL specification varies by using a high-temperature of 90 °C instead of 85 °C. Also, the change rate maximums are for air temperature, not module temperature.

You still need to decide:

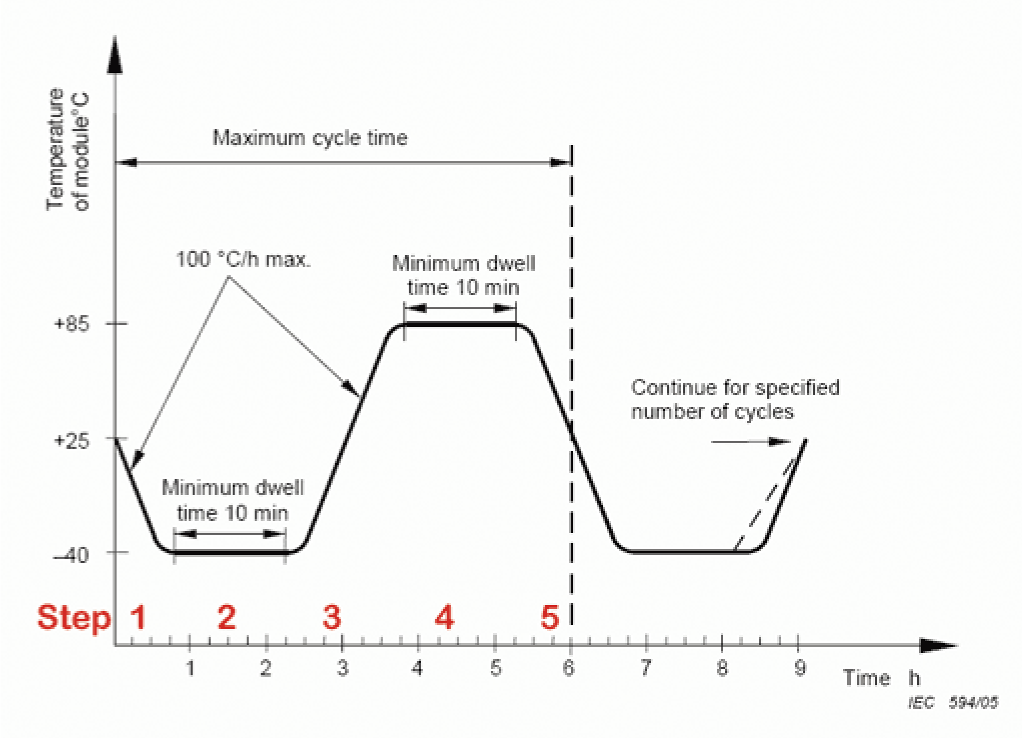
- If air temperature or module temperature will be used for primary control.
- If temperature transitions will be set as 'step' or 'controlled' ramps.
- The targeted speed of the ramps

Technical Issue:

The original version of 61646's thermal cycle test 10.11 has one additional statement, which specifies a required airflow rate. Edition 2.0 of 61646 drops this requirement completely.

Recommendation:
Refer to the latest version of this test specification.

10.11 Thermal Cycle Test Profile



Suggested test profile:

Step 1: Ramp from ambient to -40°C (100°C/hr max on module, or 39 minutes) (UL ramp is air temp.)

Step 2: Hold -40 for 10 minutes minimum (± 2°C)

Step 3: Ramp to 85 °C (100°C/hr max on module , or 75 minutes) (UL 90°C, ramp is air temp.)

Step 4: Hold at 85 for 10 minutes minimum (± 2°C) (UL 90°C)

Step 5: Ramp to 23°C (100°C/hr max on module, or 36 minutes) (UL ramp is air temp.)

Step 6: Go to step 1. Cycle 50 or 200 times. (UL 200 times)

Testing time:
Note: Total time per cycle is not to exceed six hours.

Fastest cycle time is 170 minutes / 2.8 hours (ramping at 100°C/hr)

Slowest cycle time is 360 minutes / 6 hours (ramping at 44°C/hr)

Total test time: Maximum ramp rate: 6 days or 24 days

Notes:

Maximum module temperature ramp rate is specified as 100°C/hr (1.6°C/m), and we calculate that 44°C/hr (0.73°C/m) is the minimum rate based on a maximum six hour cycle time.

61215 specifies that the 200 cycle test have modules powered when above 25°C.

ESPEC Review of 61646 10.12 Humidity-Freeze Test

See Appendix for further discussion about the challenges in adhering to the exact test requirements.

Test Profile
The following chart is from the IEC specification, and has been overlaid with red numbers indicating 'steps' as should be programmed into a test chamber.

You still need to decide:

- If air temperature or module temperature will be used for primary control.
- If temperature transitions will be set as 'step' or 'controlled' ramps.
- The targeted speed of the ramps.

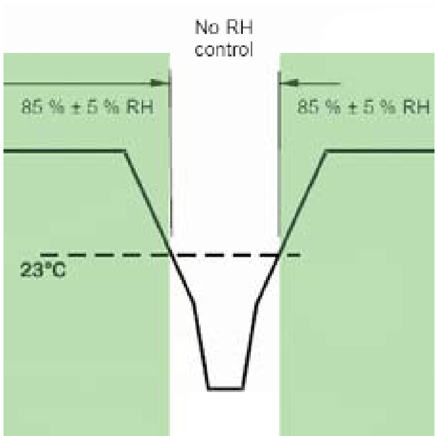
Note:

The UL specification versions of 10.11 & 10.12 (UL-1703 35 & 36) varies by specifying the change rate maximums are for air temperature, not module temperature. These maximums are also specified as 120°C/hour, instead of 100°C/hour in the IEC methods.

Technical Issue: IEC 61215 10.12 Humidity-freeze test implies humidity control during temperature ramps.

While not written, the graph of the humidity-freeze test in 61215 (and older version of 61646) shows that humidity is to be at 85% whenever the temperature is above 23°C, including heat-up and cool-down steps. See the green area in the graph at right. The specification calls for a tolerance of ±5% when humidity is on.

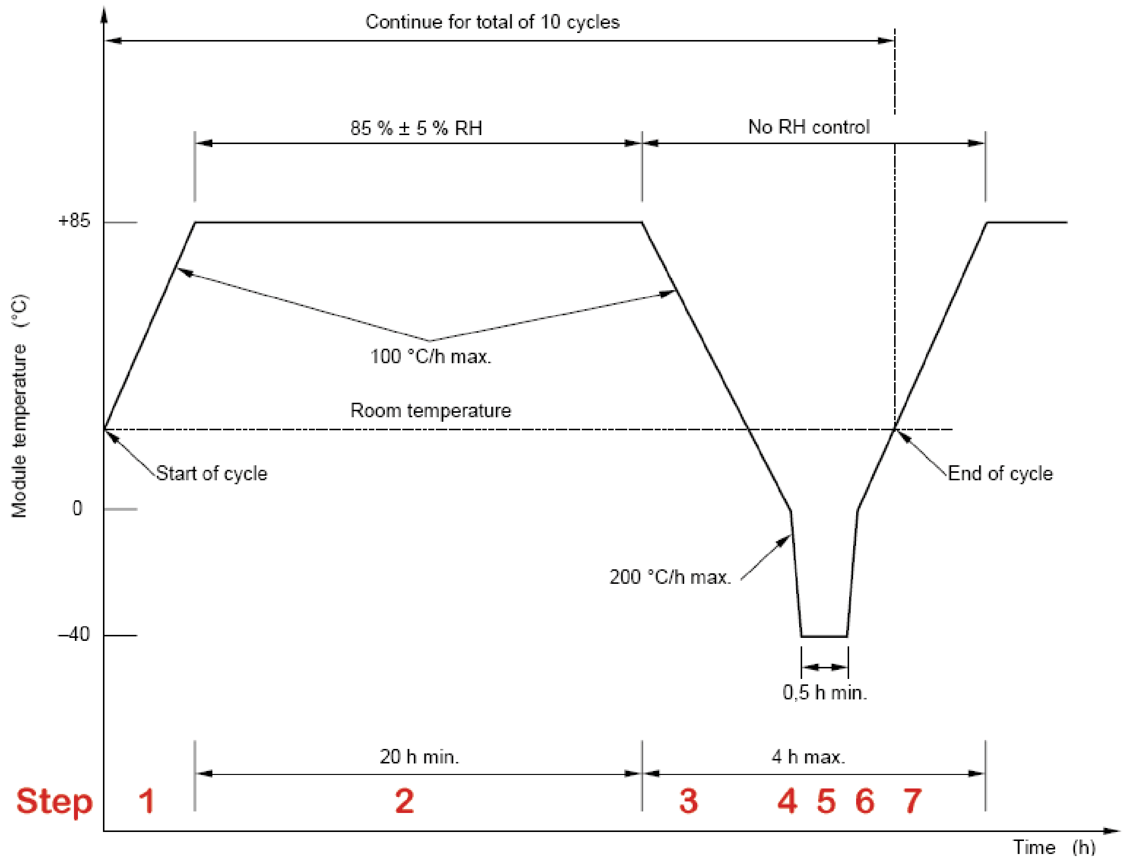
Holding a humidity level while changing temperature can be extremely difficult for a test chamber. The latest issue of 61646 corrects this by requiring humidity control only when at 85°C. However, some users may have to adhere to the methodology described in 61215, which is problematic for test chambers.



Recommendation:
We recommend interpreting the 61215 humidity-freeze test per Edition 2.0 of 61646, which corrects this problem by clearly identifying that humidity is only to be controlled while at 85°C, and not during ramps.

For further discussion, please see the Appendix.

10.12 Humidity-Freeze Test Profile



Suggested test profile:

Step 1: Ramp from ambient to 85°C / 85% (100°C/hr max on module, 36 minutes)

Step 2: Hold 85/85 for 20 hours minimum (± 2°C, ± 5%)

Step 3: Turn off humidity control. Ramp to 0°C (100°C/hr max on module, 51 minutes)

Step 4: Ramp to -40 °C (200°C/hr max on module, 12 minutes)

Step 5: Hold -40 for 0.5 hour. (± 2°C, 30 minutes)

Step 6: Ramp to 0 °C (200°C/hr max on module, 12 minutes)

Step 7: Ramp to 23°C (100°C/hr max on module, 51 minutes)

Step 8: Go to step 2. End test after ten cycles.

Note: Maximum total time for steps 3 to 7, plus step 1, is four hours. Minimum time possible is 156 minutes, or 2.6 hours

Total test time: 9.4 - 10 days

Notes:

- The freeze cycle is limited to a maximum four hours, which then allows 1.75 hours is for each cool-down and heat-up, resulting in a total minimum 71°C/hr (1.2°C/m) ramp rate.
- See Technical Issue section for discussion about differences between 61215 and 61646. ESPEC recommends following 61646 profile instead of 61215 profile.

ESPEC Review of 10.13 Damp Heat Test

This is the simplest of the tests, but also the longest. The ramp-up step can cause condensation to occur if not done properly.

You still need to decide:

- If air temperature or module temperature will be used for primary control.
- If temperature transitions will be set as ‘step’ or ‘controlled’ ramps.
- The targeted speed of the ramps.

This is an 85°C / 85% test for 1,000 hours.

Suggested test profile:

Step 1: Ramp from ambient to 85°C (100°C/hr max on module)

Step 2: Turn on humidity control. Set for 85%.

Step 2: Hold 85/85 for 1,000 hours minimum (± 2°C, ± 5%)

Step 3: Ramp to 23°C (humidity control off) (100°C/hr max on module)

Step 4: Hold 23°C/50% (humidity back on) for 0.5 hours.

Step 5: Turn off humidity control. Hold at 23°C for two hours.

Notes:

- The UL specification does not require this test.

Notes:

Specs refer to methodology from IEC 68-2-3 & 60068-2-78, which were not researched.

61646 allows for two to four hour recovery period (to ambient) at the end of the test.

Conclusion:

The specifications issued by IEC and UL are instructional in conducting useful environmental testing of PV modules and panels. There are several cases where interpretation of the requirements is open to the user without affecting the real results of the testing. Understanding these differences as discussed in this application guide will help in the purchase and use of environmental test chambers.

Sources:

IEC 61215 “Crystalline silicon terrestrial photovoltaic (PV) modules –Design qualification and type approval”, Second Edition 2005-04.

IEC 61646 “Thin-film terrestrial photovoltaic (PV) modules –Design qualification and type approval”, First Edition 1996-11. (Also named IEC 1646)

IEC 61646 “Thin-film terrestrial photovoltaic (PV) modules –Design qualification and type approval”, Second Edition 2008-05.

UL 1703 “Flat-Plate Photovoltaic Modules and Panels”, October 1, 2003.

Appendix:

Issues in complying with 61215 requirement for humidity control during ramps

The first problem is that relative humidity is dependent on the temperature. As temperature changes, relative humidity, and the range of moisture capacity of the air, also changes. This means that the amount of moisture required in the air is changing when the temperature is changing, requiring significant humidification or de-humidification to meet demand.

The second problem is that lowering temperatures requires a cold source. Like putting a glass of ice tea out on a hot, humid day, condensation will occur at this cold source. In a test chamber, this means that the air is being dried at the cooling coil, regardless of the demands of the humidity control system. The humidity system will respond by pumping more moisture in the air, and along with it, heat. This then leads to the cooling system to work harder, effectively locking the temperature system and humidity system in a battle. Depending on the temperature change rates desired, complying with this requirement may call for capabilities beyond a standard environmental chamber.

Recommendations:

We recommend interpreting the 61215 humidity-freeze test per Edition 2.0 of 61646, which corrects this problem by clearly identifying that humidity is only to be controlled while at 85°C, and not during ramps.

If referring to the latest version of 61646 is not an acceptable solution, the following information will help in strictly following 61215:

- For the cooling step from 85 to 23°C, ESPEC recommends setting the temperature transition to be as slow as possible while still complying with the test. An air temperature change rate of less than 0.8°C/m is recommended to keep the cooling demand low enough that the humidity system can maintain control.

- The heating step of 23 to 85°C can also be slowed to allow the humidity system to keep up and maintain 85%. An oversized humidity generator is also an option here, especially if faster transitions are desired.

- Note that in order to maintain 85% starting at 23°C during the heat-up step, the humidity system must be turned on earlier, so it can begin to building up to 85%. We suggest doing this at the 0°C point of the test.

Revision 1