The Importance of Extended Test Protocols for Photovoltaic (PV) Module Material Qualification

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Purpose: To highlight the advantage of requiring extended reliability test protocols for qualification of PV module materials for ensuring module reliability.

Audience: EPCs Project developers/owners, system integrators and PV module distributors.

Overview:

• **Standard test protocols** for safety and performance required for PV modules to be sold in Europe and North America are not sufficient to guarantee the materials used in PV module construction will withstand the environmental and operational stresses of a 25 year product life.

• For example, to sell PV modules in either Canada or the United States, the UL 1703 safety standard for PV modules is the **only required product qualification**. However, this standard deals exclusively with safety of the product as-built and does not attempt to evaluate product performance over its rated service lifetime.

• As new materials and technologies are introduced into the manufacturing sector of the rapidly growing PV industry, many will come from manufacturers new to the industry, some from regions of the world in which even the qualifications discussed above are unevenly applied if at all, and for whom competitiveness requires very aggressive control of and reduction of cost.

• However, the installation sector of this same industry cannot afford to compromise on those qualities that lead to reliable PV system performance over decades of field deployment. Successful projects over the long term will require reliable and predictable performance, both out of the box, and over decades of time.

• For this reason, reliability test protocols that go well above and beyond the test duration of IEC and UL are required to provide real assurance that new materials used in PV modules will perform as well as or better than existing materials, and that existing materials provide consistent performance each and every time.

• The EU standard developed by the International Electrotechnical Commission (IEC) is IEC 61215. This standard has three critical test streams that are more severe and useful than the UL 1703 protocol for assessing PV module safety and reliability.
Key Points:

- Suniva performs extended reliability product testing, for all new materials, that exceeds UL and IEC safety and performance test standards.

- In recent years, the solar PV module material landscape has expanded greatly with many new and established companies offering new material options (to lower costs/increase performance) whose quality as demonstrated through Suniva’s reliability testing and qualification varies greatly.

- Extended reliability testing for proving out long term performance ensures that new material options that allow lowering cost of PV module designs do not increase the risk of long term product failures. Figure 1 explains the difference between the UL 1703 safety standard, the IEC 61215 performance standard and Suniva’s internal testing for material qualification.

### Extended Environmental Stress Sequences

**UL1703 safety standard:**
- Thermal Cycling (TC)
  - 200 cycles of 85°C to -40°C
- Humidity Freeze Cycling (HF)
  - 10 cycles of 85% RH/85°C to -40°C

**IEC 61215 performance standard:**
- In addition to UL1703
- Damp Heat Test
  - 1000 hours at 85% RH and 85°C
- Thermal Cycling with bias
  - Current injection above 25°C
- Combined TC-HF sequence
  - 50 cycles of 85°C to -40°C, 10 HF cycles

**Suniva Material Qualification:**
- In addition to above
  - Damp Heat Test to 2000 hours
  - Thermal Cycling to 400 cycles
  - TC-HF to HF-20

*RH: Relative Humidity, C, Degrees Celsius*

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**Figure 1:** Comparison of IEC 61215 environmental stress tests compared to UL 1703 test standard and Suniva material testing protocols.
An important distinction is that UL1703 standard is a safety standard. The IEC 61215 performance standard contains a requirement on power performance after environmental stress testing. Passing IEC 61215 certification testing requires that PV modules do not degrade more than 5% after environmental stress tests.¹

- The UL1703 standard defines failures for the thermal cycling test (35) and humidity freeze test (36) solely based on safety concerns such as a risk of electric shock or breakdown of insulation characteristics.² There is no power performance requirement at all.

Additionally, the IEC61215 standard contains environmental stress tests which are not contained in UL1703. These tests identify failure modes in module design and materials. In order to mitigate risk of PV module reliability failures due to performance it is important to require that a PV panel meets both UL 1703 safety standards and the IEC 61215 performance standard.

But the basic test levels established by the IEC 61215 standard don’t go far enough to mitigate risk. Joint research presented in 2011 by QCells, BP Solar and VDE identified that extending test protocols beyond IEC 61215 levels provides good comparative data on failure modes that contribute to significant power loss, in the case of damp heat testing, or otherwise indicate trends in power degradation, in the case of extended thermal cycle testing. These data points are important indicators of strengths or weakness of PV material or module design.³

Suniva’s module lab performs extended environmental stress testing beyond the IEC 61215 test protocol. In order to ensure materials selected for Suniva’s module design are equivalent to or exceed the performance of previous design new materials are subjected to extended test sequences. Module power performance must not degrade by more than 5% while exposed to double the IEC 61215 test protocols. New material qualification for Suniva modules allows for discovery of failure modes that would not be uncovered in either a UL1703 only or IEC 61215 design qualifications.

Following are a few examples of materials that have been evaluated under Suniva’s qualification program that demonstrated poor performance and represented reliability risks. The materials were subsequently removed from consideration for use in Suniva’s solar panel design.

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¹ IEC 61215 Ed.2: Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval (2005)
² UL 1703-3 Ed.1, Flat-Plate Photovoltaic Modules and Panels (2004)
Examples:

During material qualification at Suniva’s module lab materials are regularly identified whose performance during environmental stress testing was inferior to other suppliers.

Junction Box Evaluation:

*The PV module junction box is a critical component which contains the connection point for the internal module circuitry to the external leads, houses by-pass diodes, must have good thermal characteristics, be properly rated for system voltages, and must offer protection against moisture and the environment to the current carrying conductive components necessary to connect modules in a system.*

Out of 7 junction boxes evaluated in 2011, Suniva’s module lab identified several failures due to material quality and component selection that eliminated the materials from further investigation for Suniva’s module design.

The first failure identified occurred after only 300 hours of damp heat exposure. This test failure would not have been identified under UL1703 because damp heat is not performed. Two samples, from a leading Asian manufacture of junction boxes, failed qualification testing due to material failures of the connector union that fixes the external cable lead to the junction box, see Figure 2. The plastics used in the junction box became embrittled at the elevated test temperatures and failed in such a way as to expose critical current carrying components.

Another failure was found during bypass diode thermal testing. The IEC 61215 protocol requires a current equivalent to 1.25x $I_{sc,\text{module}}$ (approximately 11.25 A) be passed through the positive and negative terminals of the junction box while the module is held at 75 C. Successfully passing the test requires that the bypass diodes remain functional and that no evidence of major visual defects is observed, among others. Suniva’s test protocol increases the current level to that which is protected by series fuses in systems utilizing them. Suniva’s design qualification program evaluates the junction box for performance up to 15 A, above IEC 61215 requirements. During this test, the plastic around the area of the diode melted, see Figure 3. Other junction boxes, including existing supplier, were exposed to the same test conditions and displayed no evidence of visual defects or degradation of materials.
Backsheet Evaluation:

The PV module backsheet is the protective layer present on the back surface of the module. The main purposes of the backsheet are to insulate the solar module circuitry and protect the internal encapsulation layers, solar cells and interconnection materials from moisture, ultraviolet radiation and weathering.

Suniva’s qualification program exceeds that of the IEC standard by subjecting backsheet materials to 2000 hours of damp heat testing while requiring insulation characteristics remain stable and power performance does not decrease by more than 5%. An example of an inferior backsheet that delaminated and cracked beyond 1000 hours of damp heat exposure is shown in Figure 4.

![Figure 4: Backsheet deterioration after 2000 hr and 1500 hr DH, respectively](image)

Encapsulation Evaluation:

The PV module encapsulation is the material responsible for sealing the solar cells inside the module and must have good optical properties, be stable at operating temperature, have the ability to withstand moisture and UV radiation.

Encapsulant qualification testing beyond the standard IEC protocol of 1000 hours uncovered differences between Suniva’s standard encapsulant, Supplier A, and an alternate material supplier, Supplier B. Supplier B’s material began to show slight trend at 1000 hours, but within the 5% requirement of IEC 61215 for power degradation. At 1500 hours and 2000 hours, module performance had dropped to 40% and 15%, respectively, for both sample modules tested using Supplier B, See Figure 5.

![Figure 5: Power degradation and increase in series resistance of EVA-B sample after DH2000, due to EVA ageing induced increase in acetic acid causing degradation of solar cell contacts.](image)
The failure mode for power degradation of Supplier B EVA sample during extended damp heat exposure was found to be caused by an increase in acetic acid resulting in corrosion of solar cell contacts, as shown in Figures 6 and 7.

![Figure 6](image1.png)  
**Figure 6:** Electroluminescence imaging of modules during Damp Heat cycling for EVA qualification. After 2000 h of damp heat exposure, Supplier B shows degradation of cell whereas Supplier A does not.

![Figure 7](image2.png)  
**Figure 7:** Visual degradation of EVA supplier B. Browning of EVA and corrosion of bus bar indicative of presence of acetic acid.

**Summary:**

Cost initiatives to reduce module cost require evaluation of new lower cost materials and low cost suppliers. The expansion of the industry in recent years has resulted in many new entrants and new materials. Cost and quality often go hand in hand. Extended product reliability testing is necessary to ensure that product performance is not sacrificed in the drive to reduce costs.

- Suniva’s qualification program has uncovered materials that demonstrate poor performance and represent reliability risk for those buying solar modules. Materials that were found to be lacking are ones that are commonly used by major module manufacturers.
- These materials can be successfully qualified to industry standards but as Suniva’s extended reliability testing shows, are less reliable than other materials.
- Suniva’s reliability testing and qualification program goes beyond industry standards and ensures we utilize materials that offer low cost to our customers without a higher risk of reliability failures.