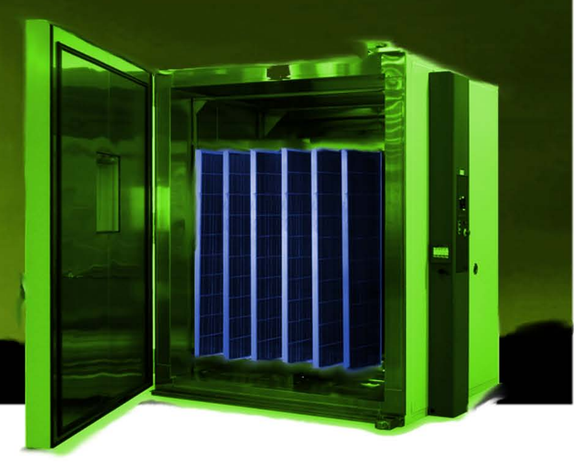
The Thresher Test

Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
Long Term Reliability and Degradation



General Test Requirements and Procedures Based on IEC 61215

SCOPE and OBJECTIVE

Currently in the c-Si PV module industry, there is no established and accepted accelerated test of a module's long term performance and reliability. Many manufacturers have proprietary testing regimens, and are using their in-house testing to ensure that their products will hold up well overtime (25+ years) as well as to privately test their competitors' modules for internal benchmarking.

Purchasers of tens of MW of modules spending considerable time working with banking institutions to access project financing are experiencing increasing module quality questions/hurdles/barriers during project financing diligence, as investors/lenders reevaluate long term investment risk due to module quality and performance assumptions.

Though PV module manufacturers strive to ship products that will survive or outlast their stated warranties, very little attention has been given to degradation pattern of those modules while in the field. Simple assumptions of a uniform and linear 0.5 - 0.7% degradation rate in module performance per year are being questioned carefully, especially when array sizes are increasing greatly and the impacts of non-linear, or non-uniform degradation on array performance are considered.

Many module manufacturers spend a considerable amount of time and money on quality, and are not able to monetize that quality given the perceived "commoditization" of the PV module market. Project developer/owner-operators are concerned about the dependability of their energy yield models in years 10-25 (the years beyond the IEC61215 testing schema). Although they want to buy quality, they have had no independent way to verify the proprietary test results shared with them under NDA.

Thus, a critical mass of manufacturers got together and jointly developed an agreed upon long term reliability and degradation testing protocol that can then be implemented by an independent testing authority/laboratory, called "The Thresher Test for c-Si PV", with the intention of bringing long-term performance test data to the market.

This proposed "Thresher Test" will describe a new long-term reliability test program that will not only help in differentiating products, but also in determining the degradation patterns of different c-Si solar modules..

This Thresher Test does not apply to modules used with concentrated sunlight.

CONTRIBUTORS & PARTICIPANTS

Sincere thanks and acknowledgement are given to the following Individuals who have participated in various ways to the development of the "c-Si Thresher Test":

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* Anthony Chia, TRINA Solar
* Regan Arndt, TUV SUD
* Robert Puto, TUV SUD
* Kenneth Sauer, YINGLI SOLAR

SAMPLING

Eight modules (plus spares as desired) shall be taken at random by a Third Party from a production batch or batches, in accordance with the procedure given in IEC 60410.

The modules must have been fabricated based on manufacturer's BOM and in accordance with the relevant drawings, process specifications / inspections and quality control.

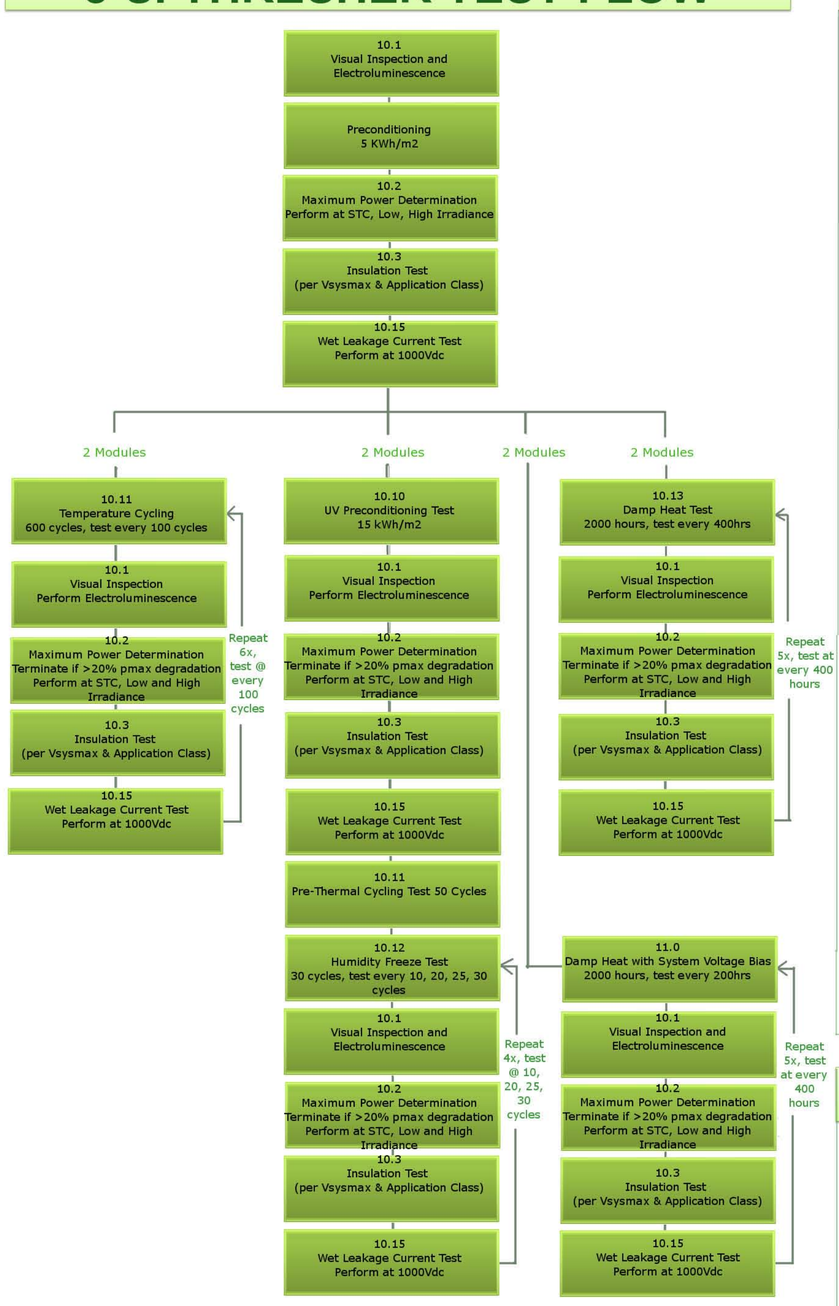
The modules shall be submitted together with manufacturer's Safety Installation Manual showing handling, mounting and connection instructions including maximum permissible system voltage, power rating, application class.

MARKING

All eight modules shall carry the following clear and indelible markings:

– Manufacturer's Name or Symbol
– Model Number
– Serial number
– Power Rating
– Maximum system voltage for which the module is suitable
– Traceability: date and place of manufacture

c-Si THRESHER TEST FLOW



TEST DESCRIPTIONS & CONDITIONS

Seq. Clause No.	IEC 61215 Ref. Clause	Title	Test conditions
10.1	10.1	Visual Inspection	See detailed inspection list in 10.1.2
10.2	10.2	Maximum Power Determination	See IEC 60904-1
10.3	10.3	Insulation Test	Dielectric withstand at 1 000 Vdc twice the Maximum systems voltage for 1 min. For modules with an area of less than 0,1 m2 the insulation resistance shall be not less than 400 MΩ. For modules with an area larger than 0.1 m2, the Measured insulation resistance times the area of the module shall be not less than 40 MΩ/m2 measured at 500 V or maximum systems voltage, whichever is greater
10.4	10.10	UV Preconditioning Test	15 kWh/m^{2}total UV irradiation in the wavelength range from280 nm to 385 nm with 5 kWh/m^{2}UV irradiation in the wavelength range from 280 nm to 320 nm
10.5	10.11	Thermal Cycling Test	50 and 600 cycles from –40 °C to + 90 °C with STC peak power current applied during the 600 cycles only. Test at every 100 cycles increment.
10.6	10.12	Humidity Freeze Test	30 cycles from + 85 °C, 85 % RH to –40 °C Test at every 10, 20, 25, 30 complete cycles
10.7	10.13	Damp Heat Test	2000 hours at + 85 °C, 85 % RH Test at every 400 hours increment.
10.8	10.15	Wet Leakage Current Test	See details in IEC 61215 clause10.15 For modules with an area of less than 0.1 m2 the insulation resistance shall be not less than 400 MΩ. For modules with an area larger than 0.1 m2 the measured insulation resistance times the area of the module shall be not less than 40 MÙ/m2 to be measured at 500 V or maximum systems voltage, whichever is greater
10.9	Not included	Electroluminescence	V=Voc, I= 1/2 Imp
10.10	Not included	Damp Heat with System Voltage Bias	2000 hours at 85C, 85% RH Test at every 400 hours increment

CHAMBER TEST PROFILES

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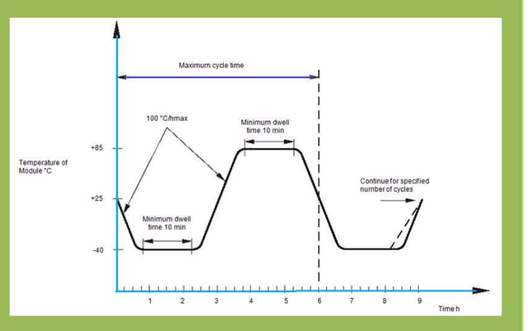
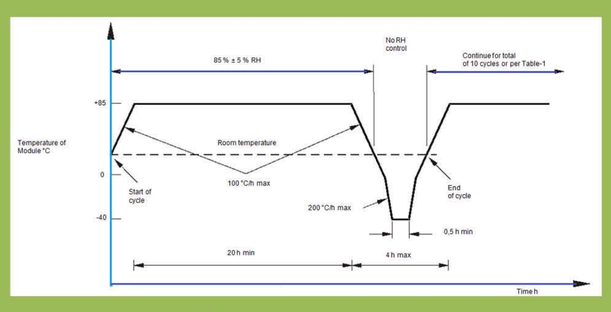
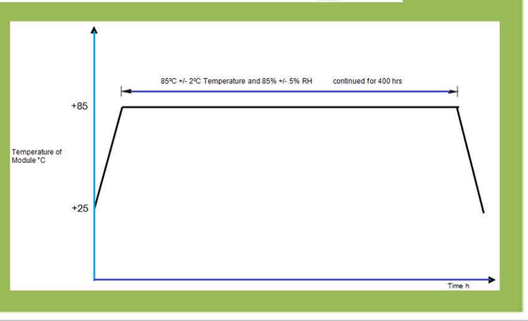


HF



DH



DAMP HEAT w/ SYSTEM VOLTAGE BIAS

Purpose / Objective

Long term degradation by system bias voltage is not covered in IEC 61215 standards. This test is designed to determine the ability of the module to withstand the effects of long-term penetration of humidity with high temperature and system voltage bias. Studies in the industry have shown that in areas where it is hot and humid, there is a greater sensitivity of mc-Si PV modules to system voltage bias degradation. In such environments, damp heat with System Voltage bias enable greater ionic current flow through the module resulting to Sodium ions (Na+) migrating to the TCO / glass interface causing delamination of the TCO, an electro-chemical corrosion. - Some known key drivers are negative cell polarity, moisture ingress, temperature, sodium content in glass and from the atmosphere. (Reference: Peter Hacke, NREL "System Bias Voltage Stress Effects in Multicrystalline Silicon Modules")

System Voltage Bias

- Module 1: Damp Heat with +Ve voltage bias (or as per manufacturer's grounding instructions)
- Module 2: Damp Heat with -Ve voltage bias (or as per manufacturer's grounding instructions)

- The magnitude and polarities of the system voltage should be in accordance to the manufacturers nameplate system voltage rating and applied to the shorted module leads with respect to the grounded module frame.

DATA and RESULTS

The "Thresher Test" goal is not a Pass / Fail test but rather a test designed to gather and report degradation through the course of the test sequences described in Table-1 and Test Flowchart

The Test cycles / hours are as follows:
-Temperature Cycle = 600 cycles at 100 cycles interim test points / pulls

-Damp Heat with and without System Voltage Bias = 2000 h at 400h, 800h, 1200h, 1600h, 2000h interim test points / pulls
Note: maybe increased to 2500h if 2kh does not provide sufficient degradation to differentiate and to reflect >10, <25 years performance warranty

-Humidity Freeze = 30 cycles at 10, 20, 25, 30 cycles interim test points / pulls

Testing shall be terminated when one of the following is encountered or achieved:

A. the maximum power output power degradation reaches >20% from initial power rating test data
B. the maximum test sequence cycles / hours are completed

Record and report the following at the beginning and at the end of each test sequence pulls:
-power drop
-leakage current reading
-Visual observations / visual evidence of major defects as described in IEC 61215, Clause-7

DATA REPORTING

The "Thresher Test" data and results will be reported by the 3rd Party Testing Laboratory to the Manufacturer who may decide to publish it, as they see fit.

The Manufacturer can only publish their own data.

The data and results will ultimately be used by Buyers / Developers to enable them to set their own threshold and suit their own requirements.

REFERENCES

IEC 61215:2005, Crystalline silicon terrestrial photovoltaic (PV) modules – Environmental testing – Part 1: General and guidance

Peter Hacke, NREL "System Bias Voltage Stress Effects in Multicrystalline Silicon Modules"

IEC 60068-2-21:1999, Environmental testing

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IEC 60904-1:1987, PV devices – Part 1: Measurements of PV current voltage characteristics

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IEC 60904-10:1998, Photovoltaic devices – Part 10: Methods of linearity measurements

IEC 61853: Performance testing and energy rating of terrestrial photovoltaic (PV) modules 1

ISO/IEC 17025:1999, General requirements for competence of testing and calibration laboratories.

CONTACT INFORMATION

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