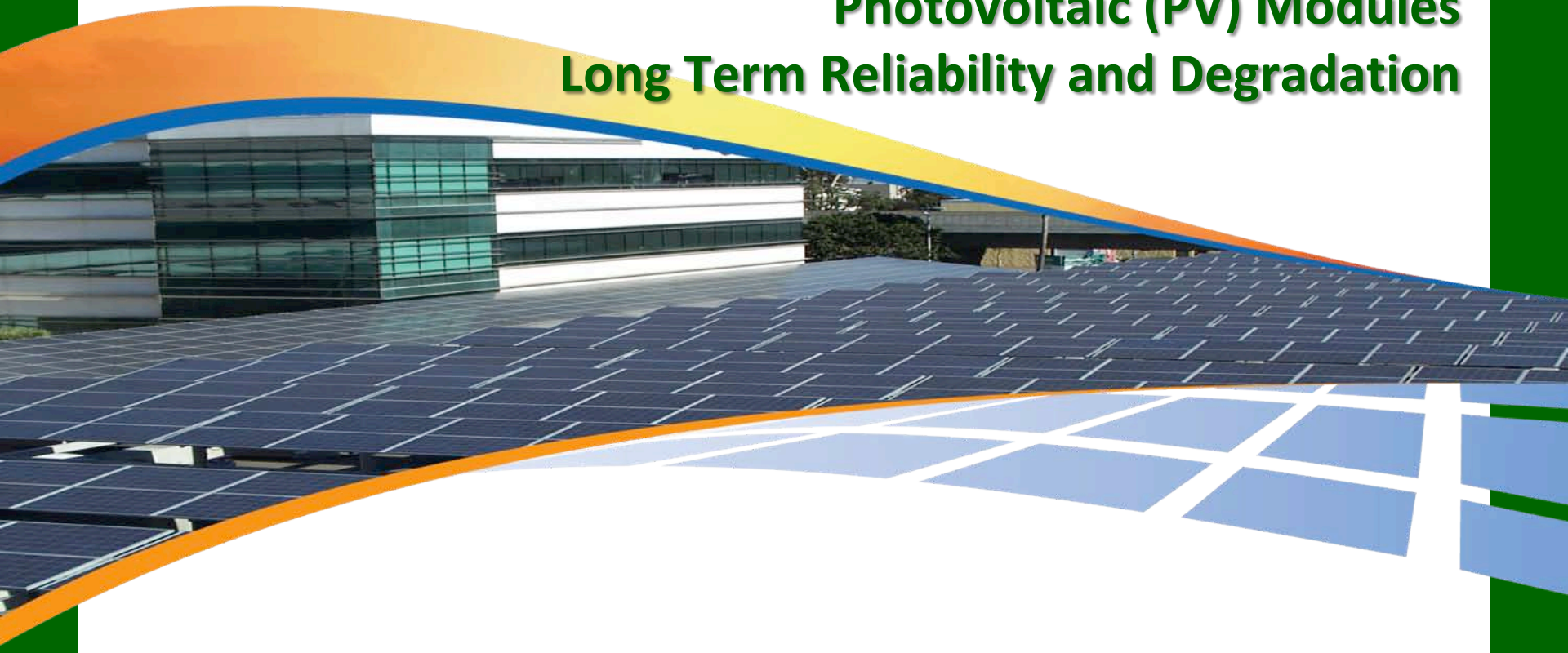
"The Thresher Test"
Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
Long Term Reliability and Degradation



International PV Quality Forum
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Why Module Reliability Matters

Financing

- Projects using "unreliable" modules (real or perceived) do not get financed.
- Module "quality" impacts lenders' debt levels due to lower IE yield estimates.

Operations

- Module failures cost real money to remedy
- Module degradation has many negative unintended consequences

Performance

- Area under the curve = $ or ¢
- Future energy sales, and thus returns, are subject to large variables

Lack of clear performance and reliability data has module suppliers stuck in "commodity" mode. But we KNOW modules are not commodities – yet.

A Buyer frequently ask…

How do I KNOW that the module I am buying will perform as advertised?

Hint: Not by the warranty.

Another Hint: Not by UL or IEC certifications.

Trust? Company reputation? I have no idea!

(Role of the **Thresher Test**…)

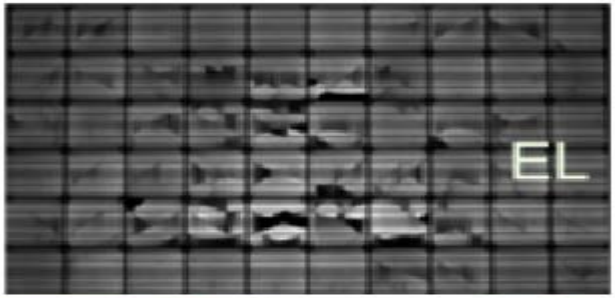
Motivation-1

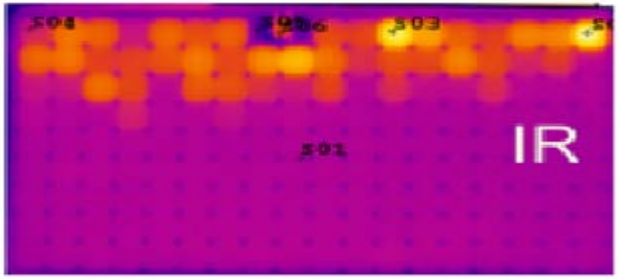
- Currently in the c-Si PV module industry, there is no established and accepted accelerated test of a module's long term performance and reliability.

- 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.

Motivation -2

- Purchasers of tens of MW of modules are 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.

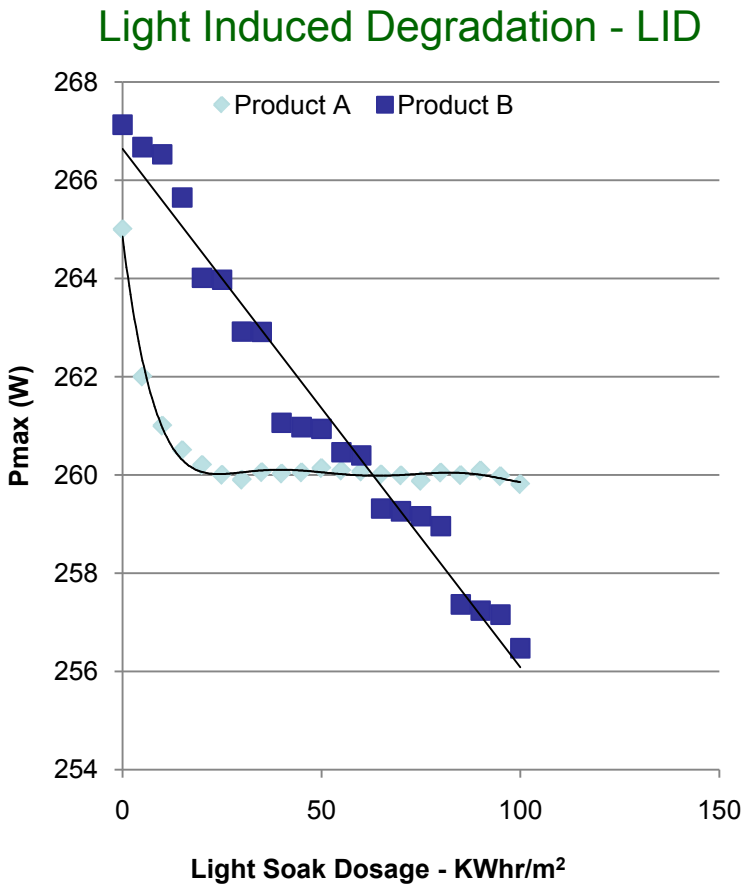




Motivation -3

- 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.



Motivation - 4

- 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.

Buyer's or Developer's wish…

"The industry expanded standardized accelerated testing to much longer cycle times ***to separate the wheat from the chaff***."

A wish came true…

- **A critical mass of manufacturers, 3rd Party Test Labs, NREL, and NCB 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.**

Govindasamy Tamizh-Mani, ASU/TUV Rheinland
Daniel Cunningham, BP SOLAR
Matthew Blom, DuPont Photovoltaics Solutions
Sunil Panda, DuPont Photovoltaics Solutions
Keith Shellkopf, KYOCERA
Glenn Tomasyan, MITSUBISHI
Peter Hacke, NREL
Sarah Kurtz, NREL
Jenya Meydbray, PVEL
Cherif Kedir, RETC
David King, Sandia Labs

Alex Marker, SCHOTT
Paul Wormser, SHARP
Michael Lasky, SHARP
Bill Richardson, SOLON
Neil Shey, SOLON
Jan Carstens, SOLON
Oliver Koehler, SUNPOWER
Monali Joshi, SUNTECH
Wei-Tai Kwok, SUNTECH
Jon Haeme, TRINA SOLAR
Anthony Chia, TRINA SOLAR
Regan Arndt, TUV SUD
Robert Puto, TUV SUD
Kenneth Sauer, YINGLI SOLAR

Hugh Kuhn, Solar Power Partners, - **Program Leader**
Alelie Funcell, RETC - **Program Coordinator**

So what is "The Thresher Test" ?

- "The Thresher Test for c-Si PV", intends to bring 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.

How samples are selected – Random 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.

How products are identified

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

– Manufacturer's Name or Symbol

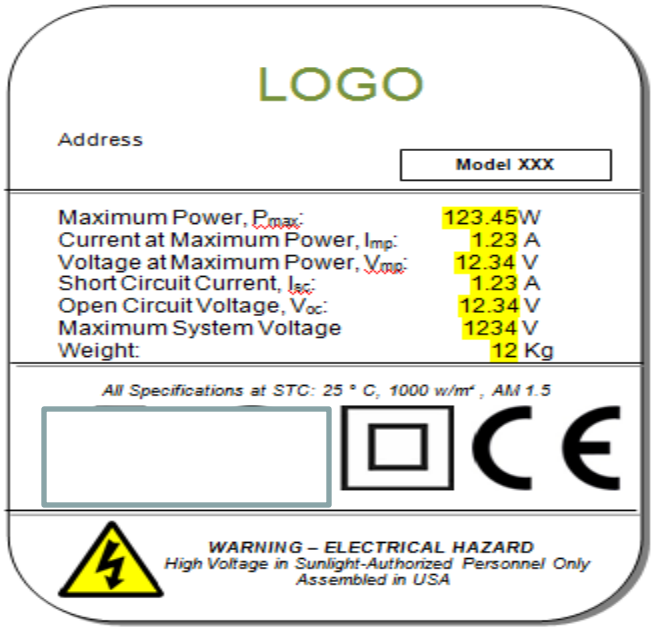
– Model Number

– Serial number

– Power Rating

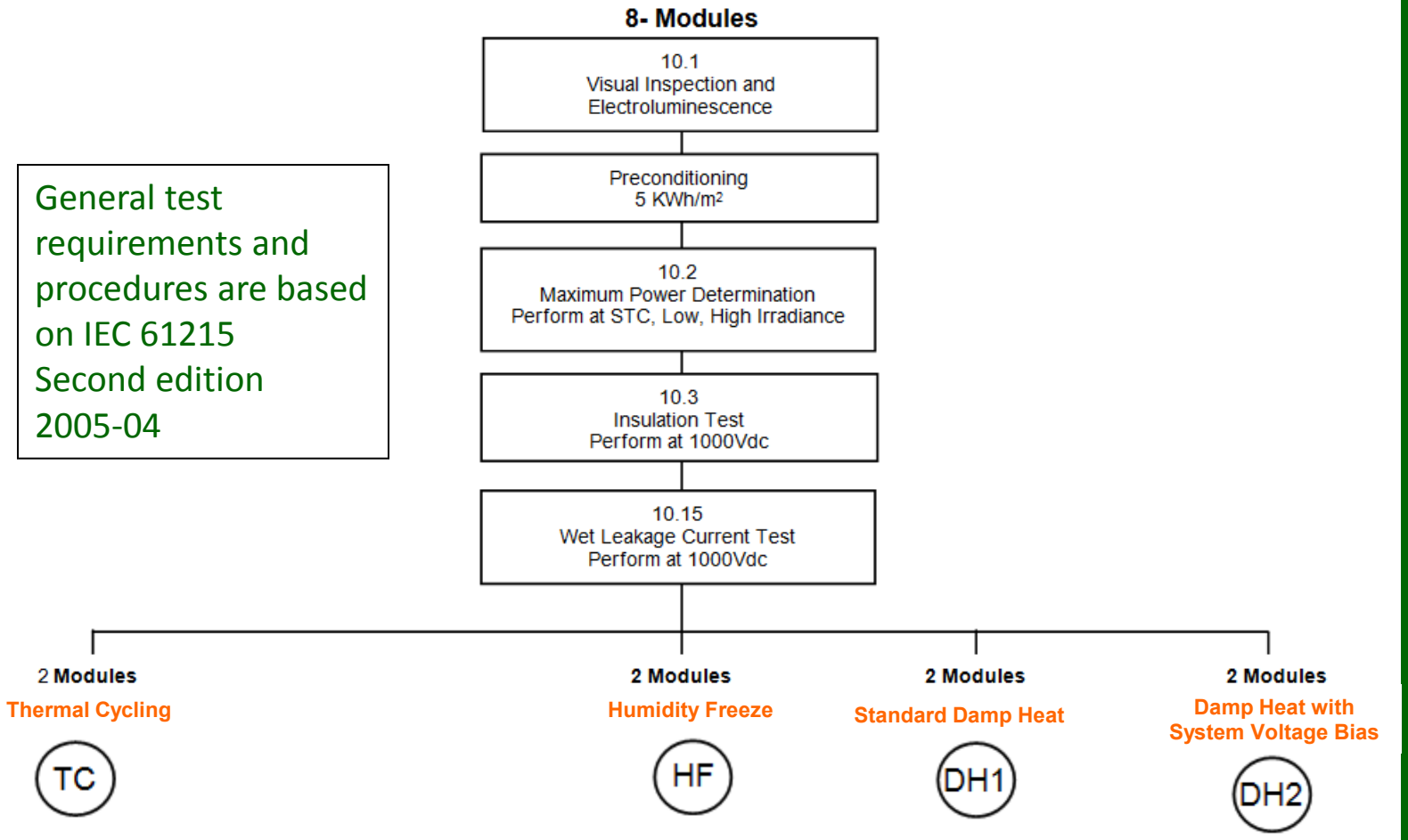
– Maximum system voltage for which the module is suitable

– Traceability: date and place of manufacture

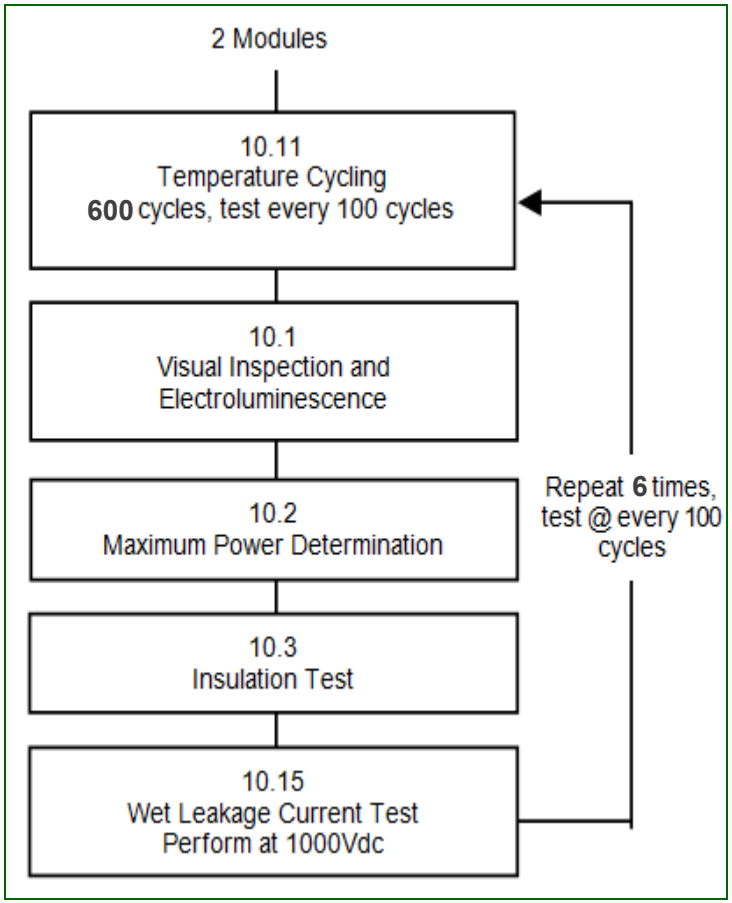


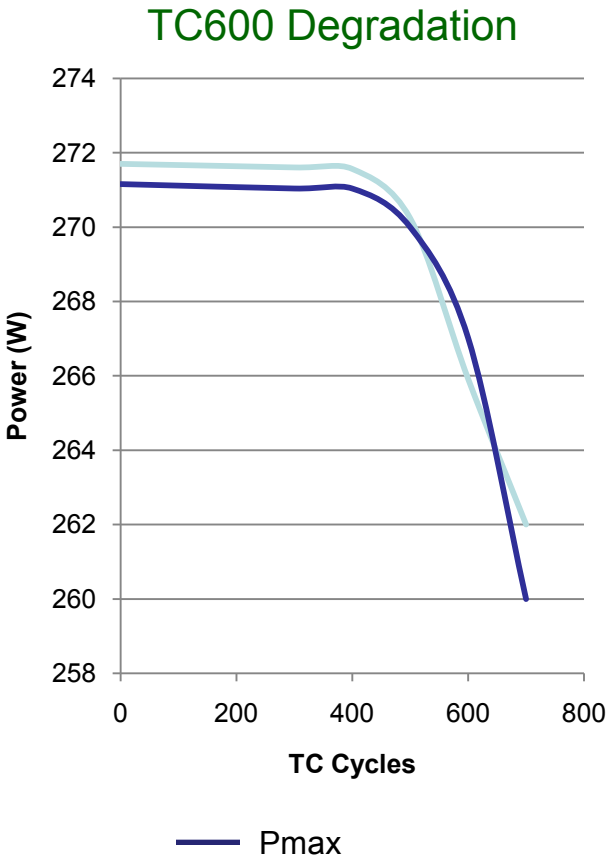
"c-Si Thresher Test" Process Flow: *data is taken at interim pulls to show degradation trends, not only initial and final test points*

General test requirements and procedures are based on IEC 61215 Second edition 2005-04

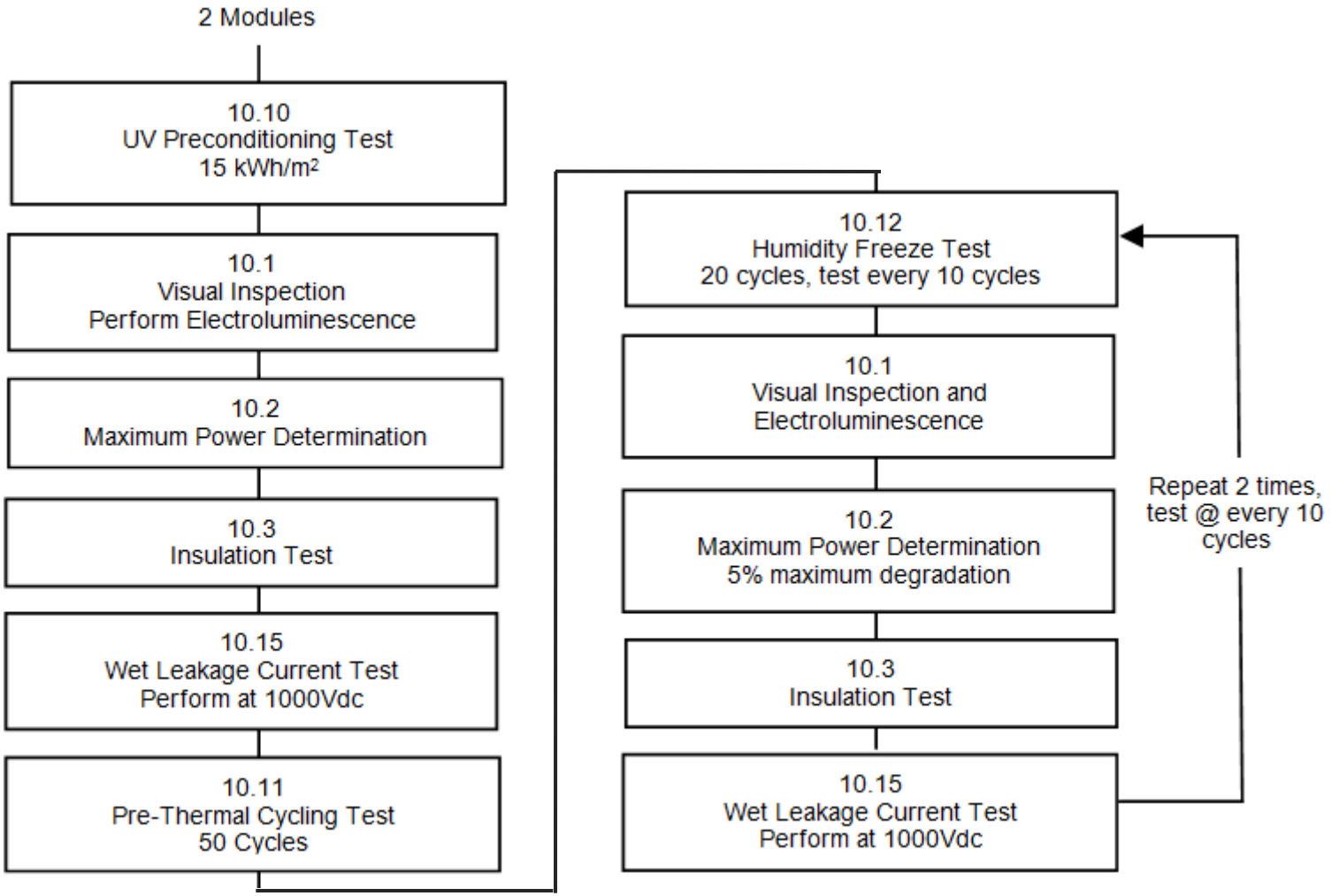


Thermal Cycling Flow

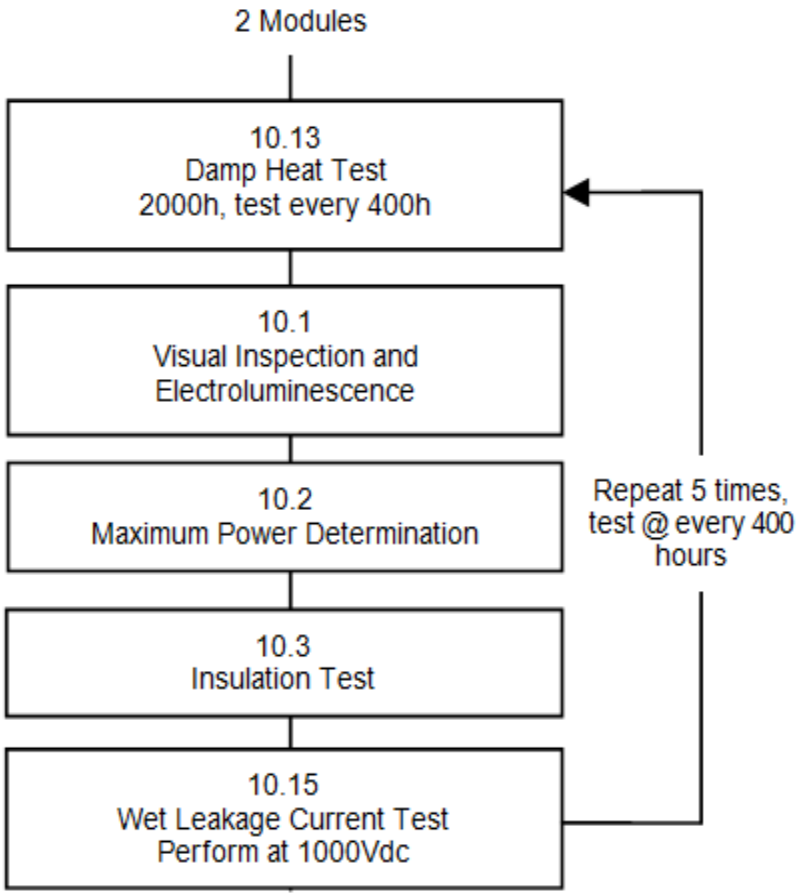


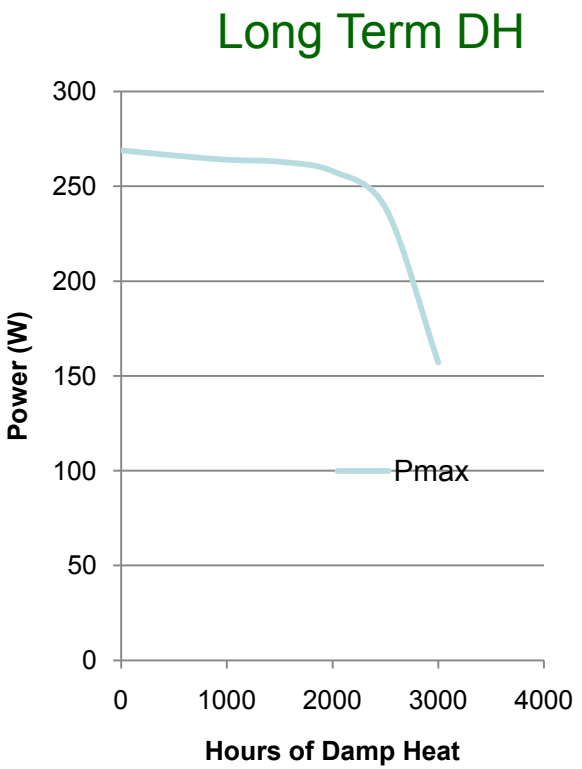


Humidity Freeze Flow



Standard Damp Heat Flow





Damp Heat with System Voltage Bias - Motivation

- Over the past decade, there have been observations of module degradation and power loss because of the stress that system voltage bias exerts.

- This results in part from qualification tests and standards not adequately evaluating for the durability of modules to the long-term effects of high voltage bias that they experience in fielded arrays.

•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

- Test duration: Test after increments of 400 hours performed 5-times up to 2000 hours

Reference:

Requirements for a Standard Test to Rate the Durability of PV Modules at System Voltage

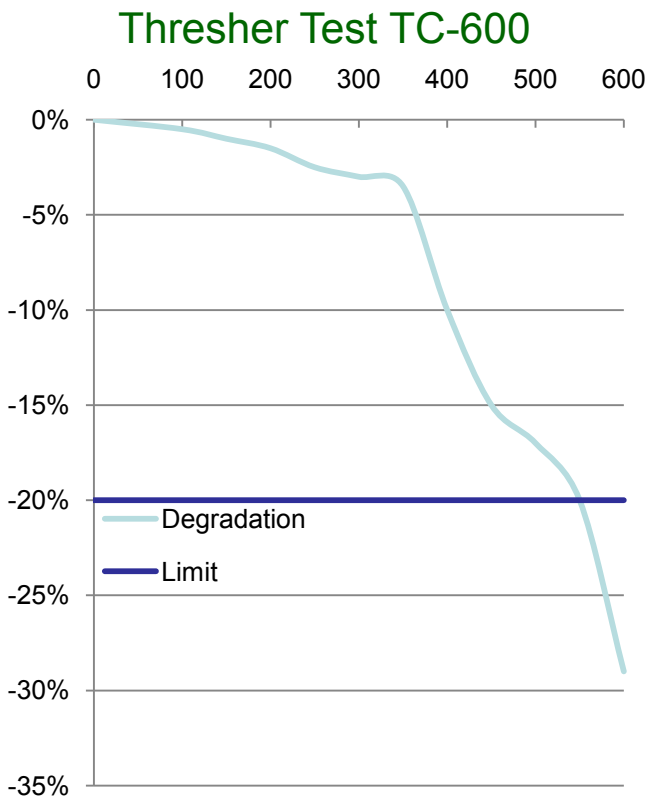
Presented by: Peter Hacke, NREL "System Bias Voltage Stress Effects in Multicrystalline Silicon Modules"

How Data and Results are treated

- ❑ 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

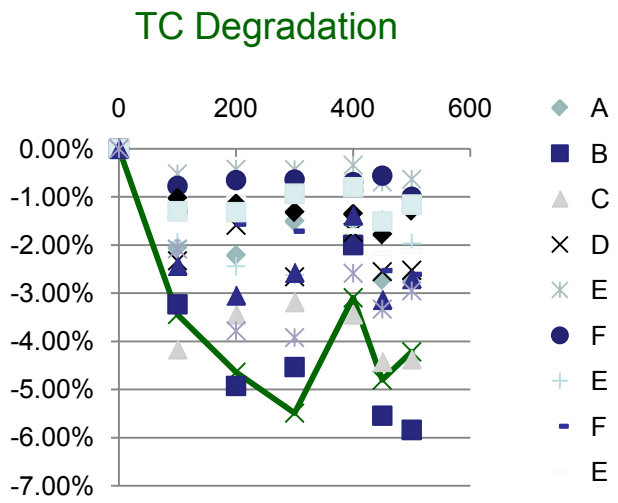
- ❑ Testing shall be terminated when one of the following is encountered or achieved:
  - A. the maximum power output power degradation reaches >20% from initial power rating test data
  - B. the maximum test sequence cycles / hours are completed

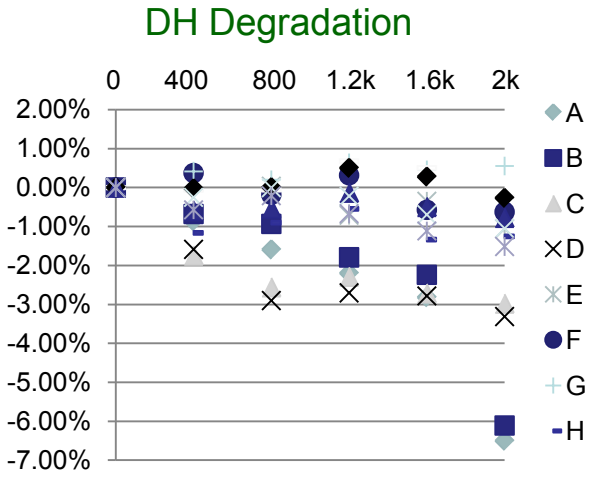
- ❑ Record and report the following at the beginning and at the end of each test sequence read point:
  - power drop
  - leakage current reading
  - Visual observations / visual evidence of major defects as described in IEC 61215, Clause-7 (full BOM including JB, Cable & Connectors)



How is data reported

- 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.





Why "Thresher Test"? Because stuff happens.

Ensuring quality and reliability of PV modules is **HARD**.

The number of manufacturing process steps that have to be flawless is **HUGE**.

The dependence on quality of upstream suppliers is **REAL**.

Knowing these things are true, we need to jointly do something to improve PV durability.

THANK YOU!

"The Thresher Test" Team

Any Questions?

Contact Information

For further questions, please contact:

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