Photovoltaic Module Reliability Workshop
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Golden, Colorado

Nicholas Bosco, NREL
Thermal and Mechanical Fatigue

- What are the appropriate number of thermal cycles for a long-term reliability test
- Should this number be climate specific
- What is the effect and appropriate level of DML testing
DML: FEM and mechanical loading

DML fatigues ribbon interconnects

cell-to-cell strain
−3 kPa to +3 kPa
measured and simulated
dynamic mechanical loading

Poster 43:
In-situ impedance measurement in c-Si PV modules during rapid thermal cycling

\[ \Delta \varepsilon = \varepsilon_f N_f^C \]

\[ \Delta \varepsilon_{105C} = 2.5\% : \]

\[ N_f^{\text{offset}} = 3726 \]

\[ N_f^{\text{no-offset}} = 2420 \]

\[ N_f \approx 3000 \]

Failures only evaluated during in-situ measurement
thermal cycling and service

Normalize by the number of cycles to failure for the ± 1kPa DML cycle or the IEC TC cycle

25 years is equivalent to less than 175 cycles

*This evaluation must be qualified for the specific module evaluated.
Extended Thermal Cycling: 13 Models (multi- / mono-c-Si, FY2011~)

- **Initial Value**
  - TC: 200 cycles
  - TC: 400 cycles
  - TC: 600 cycles

- **Mean +/- SD**
  - (N = 10 or 5)

- **5% Degraded Line**
  - 2/5 : > 5% Degraded
  - 3/5 : > 5% Degraded
  - 5/5 : > 5% Degraded

- **Bypass Diode Breakdown**

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**Model ID**

- A-1
- B-1
- C
- E
- F
- G
- H
- I
- J
- K
- M
- N
- O

Asia Standards and Conformity Assessment Promoting Project (JP), 2011-2014
thermal cycling: current work

Uncertainty analysis:
Monte Carlo simulation
Laminate material properties and geometry

example data
**PVQAT TG2**

**TC**: 500 independent of climate zone

**DML**: ±1kPa, 1000 cycles in UV/TC/HF/DH sequence

Challenge: Failures are typically due to a quality excursion

simulating an entire year

A year in Oak Ridge, Tenn. does 70% as much damage as a year in Golden, Colo.