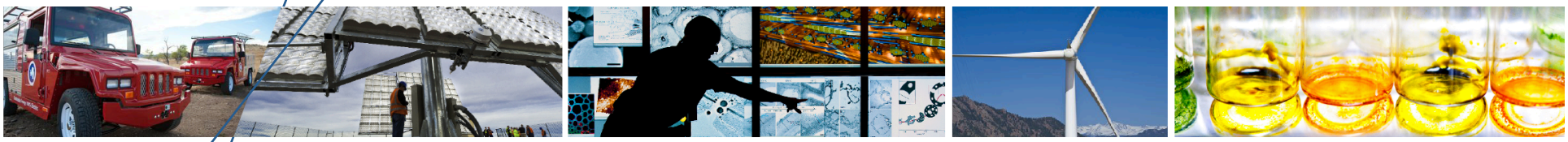
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Group 3
Humidity, Temperature and Voltage



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NREL PVMRW 2013

Introduction

- **Group 3 is chartered to develop accelerated stress tests that can be used as comparative predictors of module lifetime versus stresses associated with humidity, temperature and voltage.**
- **The tools we have to utilize are:**
  - **Outdoor test results**
  - **Accelerated stress tests results**
  - **Modeling**

Where we stand today

- The module qualification test sequence IEC 6121 (first published i 1993 contains a 1000 damp heat test (8 °C at 85% RH).
- This stress tes appears to do an excellent job of screening ou module designs an materials that would fail in the field in short time periods.
- So Group 3 must look to find field failures that are no identified in the 100 hour damp heat test, bu are limiting the lifetime of PV modules.

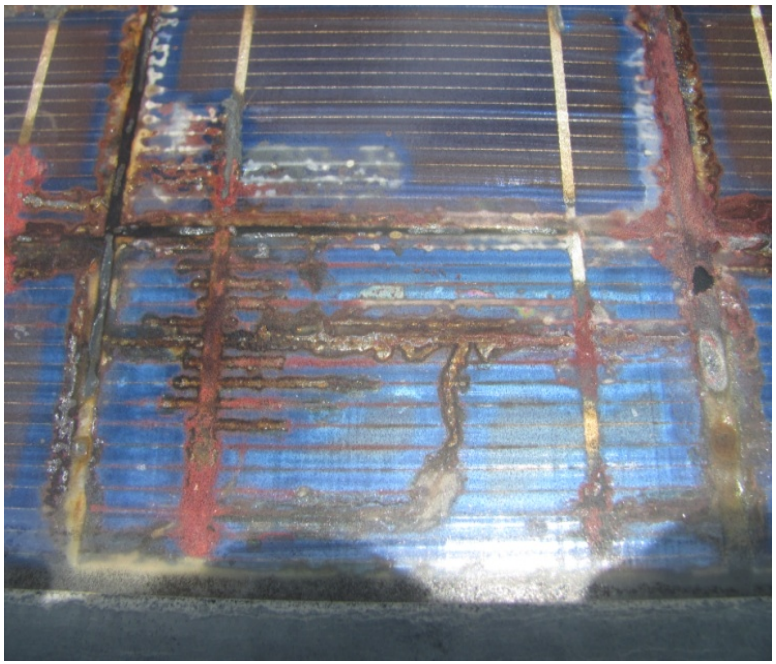
What has Group 3 been doing

- Making observations of field failures.
- PID Testing – Adding voltage to H and T
  - Have paper by Peter Lechner of ZSW
  - Have more posters on PID than any other subject
- Modeling to understand conditions within module
  - Mike Kempe will give paper on this work
  - This is critical because you can't understand accelerated stress test results if you don't understand the conditions during the test and the conditions that occur in the field
- Effectiveness of Qualification Test
- Look at results of testing beyond qualification

Field Results

So what do we say today in terms of wear out failures that are likely due to humidity?

- **Most of the evidence of corrosion comes in conjunction with delamination**
- **Any of the metals (grid lines, interconnect ribbons, solder bonds) will likely corrode if exposed to liquid water.**
- **So even if our contacts can survive moisture in the encapsulant they are not likely to survive very long after failure of the encapsulation package.**

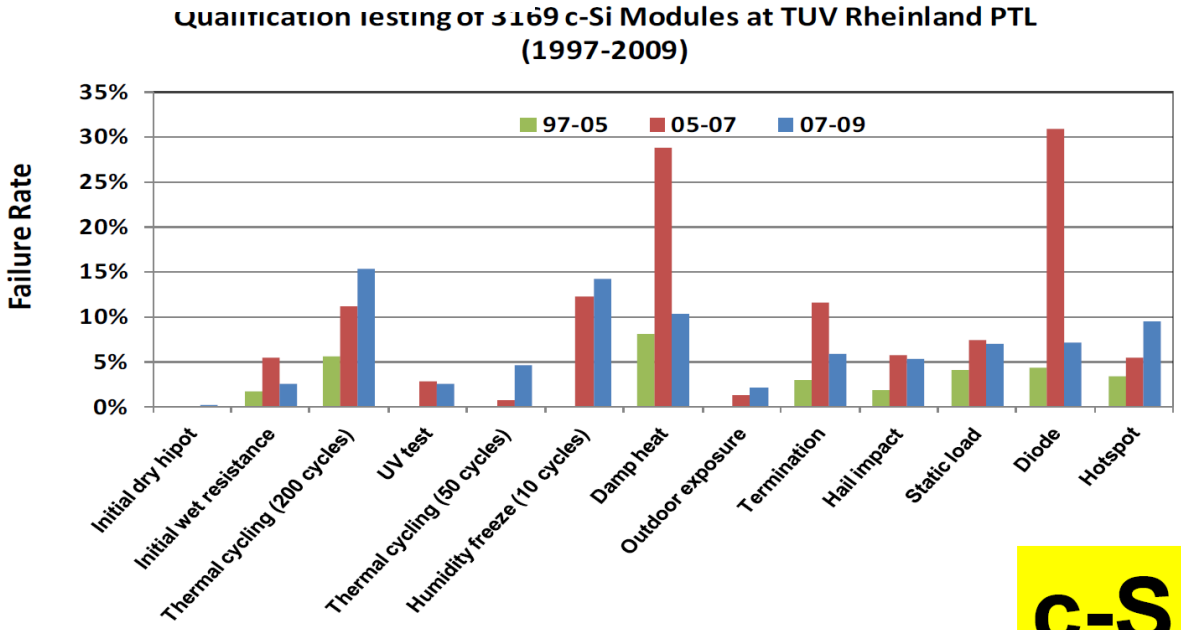


Field Results and Damp Heat Testing

Observed Field Failures

Types of Failures	% of Total Failures
Corrosion	45.3
Cell or Interconnect Break	40.7
Output Lead Problem	3.9
Junction Box Problem	3.6
Delamination	3.4
Overheated wires, diodes or terminal strip	1.5
Mechanical Damage	1.4
Defective Bypass Diodes	0.2

Wohlgemuth et.al. 20th EUPVSEC 2005



Tamizhmani 2010 PVMRW

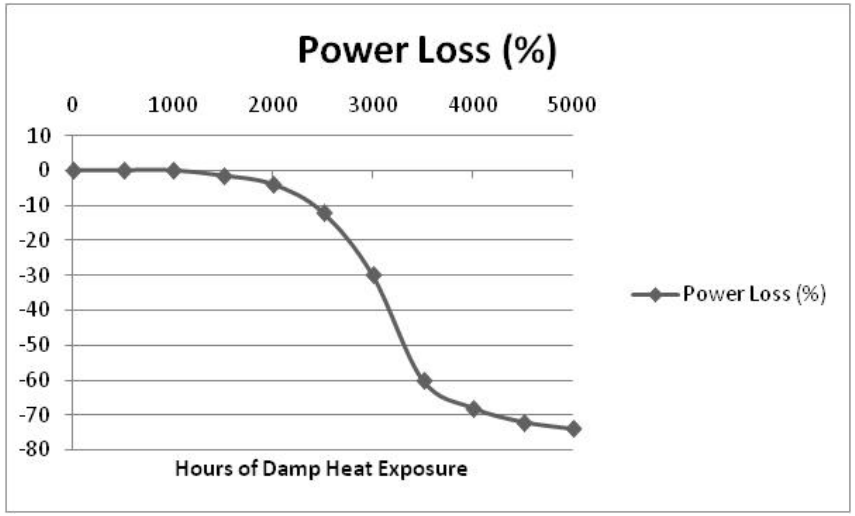
c-Si

Damp Heat Test Results

- When damp heat test was first introduced it was the hardest test for most PV module manufacturers to pass.
- Even when you did pass damp heat the power loss was usuall approaching the 5% limit.
- When wet hi-pot test was added in 2005 many more module types failed after damp heat until they learned how to control the leakage current.
- As late as 2008 in 23rd EUPVSEC I reported on experiment where BP tested 10 different cry-Si modules (all of which carried IEC 61215 labels) from 9 different manufacturers from around the world to 1250 hours of damp heat, the standard test at BP Solar. 8 out of the 10 module types suffered more than 5% power loss in this experiment.
- Over the years the manufacturers learned how to reduce and eventually eliminate any power loss from 1000 hours of 85/85 testing.
- So it doesn't take extraordinary measures to get through 1000 or even 1250 hours at 85/85 with no measureable power loss.

Extended Damp Heat Testing

- **So if 1000 hours of damp heat testing helped improve field performance maybe longer test times would provide a measure of longer term survival.**
- **See my results from 2005.**
- **Many other publications show similar results**
  - **Herrmann et. al. 37th IEEE PVSC 2011**
  - **Saint-Lary et. al. 27th EUPVSEC 2012**
- **This type of degradation occurs in cry-Si modules with EVA encapsulant and breathable polymeric backsheets.**

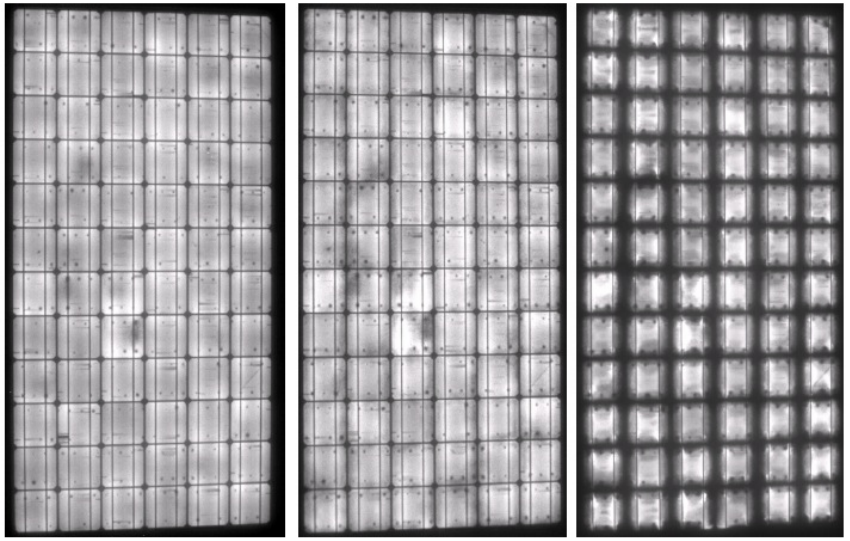


Wohlgemuth et.al. 20th EUPVSEC 2005

Degradation Signature

- **The dark area around the outside of each individual cell indicates that this area of each cell is no longer actively collecting carriers.**
- **This is due to moisture induced corrosion of the doped oxide that provides the electrical contact to the emitter of the silicon cell.**
- **Problem is, no one has reported seeing this degradation signature in PV modules from the field.**
- **This failure mode may never occur in the field or may take longer than present field exposure times (> 30 years).**

Electroluminescence pictures of a Cry-Si module after extended damp heat testing.



1000 hours 2000 hours 3000 hours

Saint-Lary et. al. 27th EUPVSEC 201

SUMMARY

- At present time we do not believe that damp heat testing beyond 1000 hours is justified.
- Looking for combined sets of stresses that can lead to delamination. Possibilities
  - UV and temperature
  - Dynamic mechanical loading/thermal cycling/humidity freeze.
- We are looking for:
  - Older arrays (>15 years) exposed in hot/humid environments to visit.
  - Reports on and samples of product returns that appear to be humidity and temperature related.