Design Verification Testing

NREL PV Module Reliability Workshop

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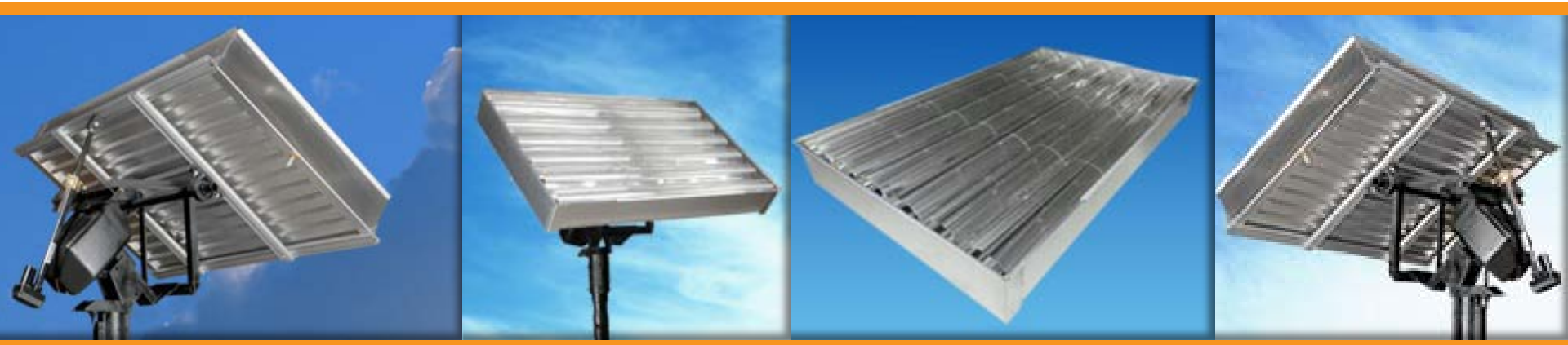
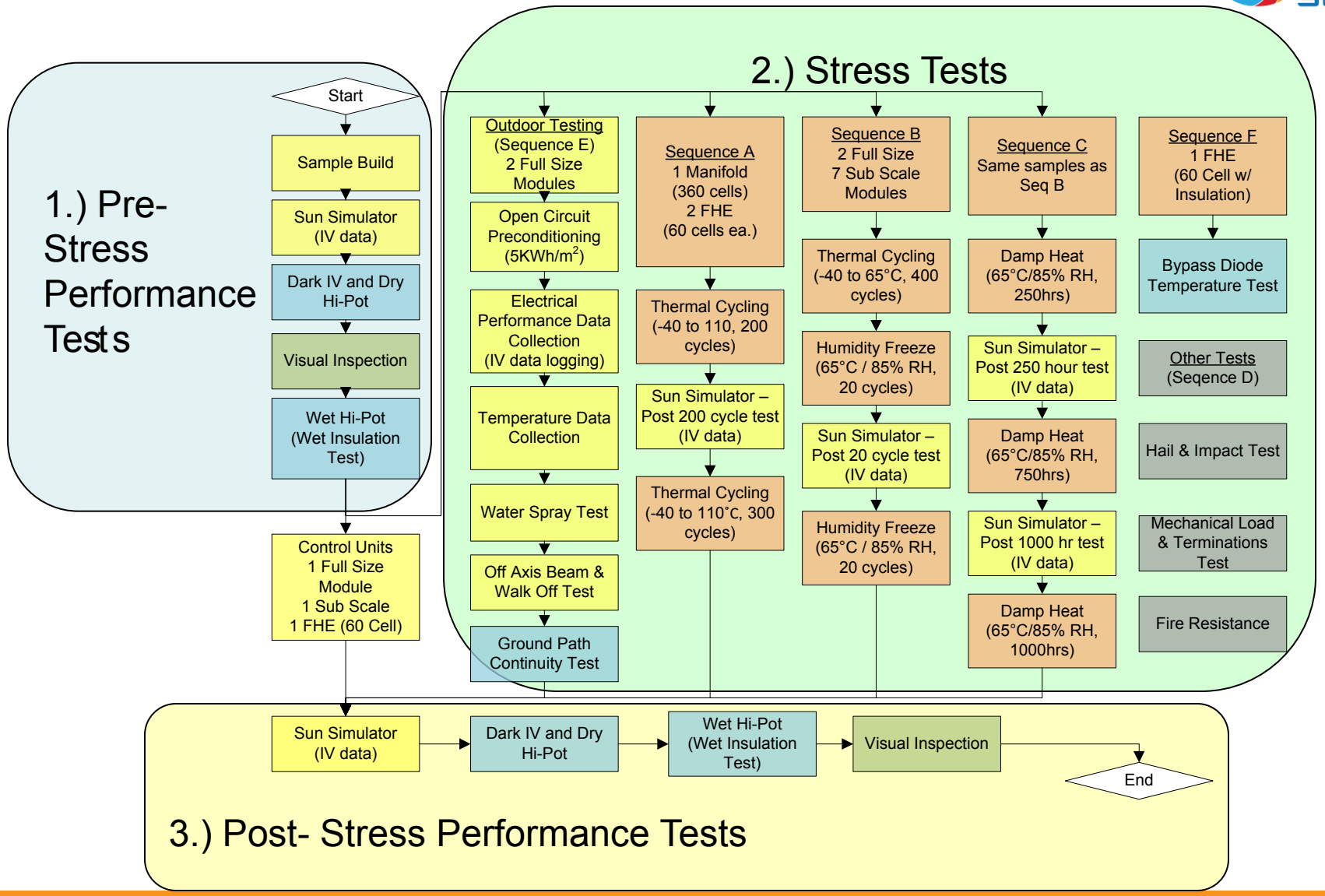
2-18-10

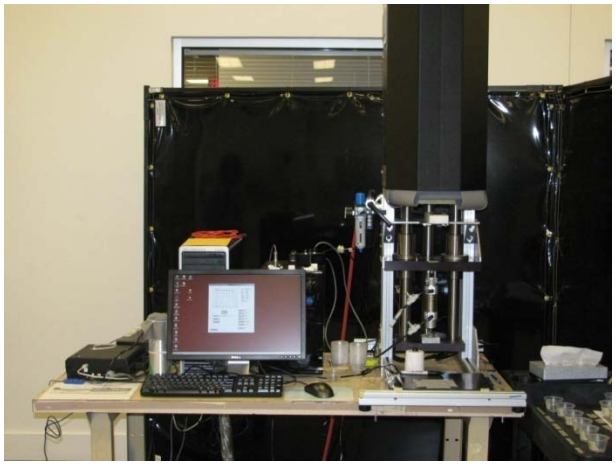


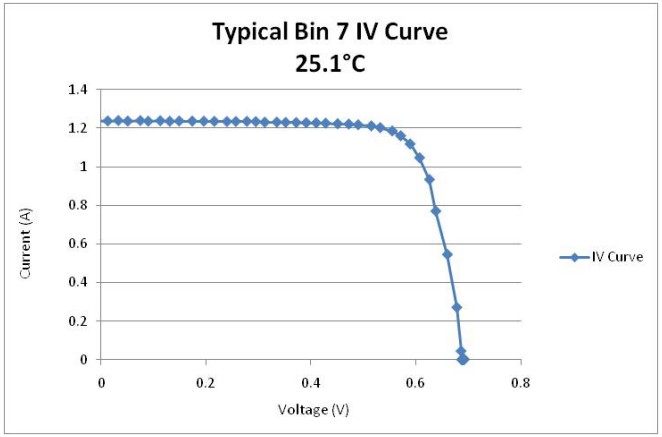
DVT Testing Sequence



Concentrated Solar Cell Testing

Custom Cell Tester



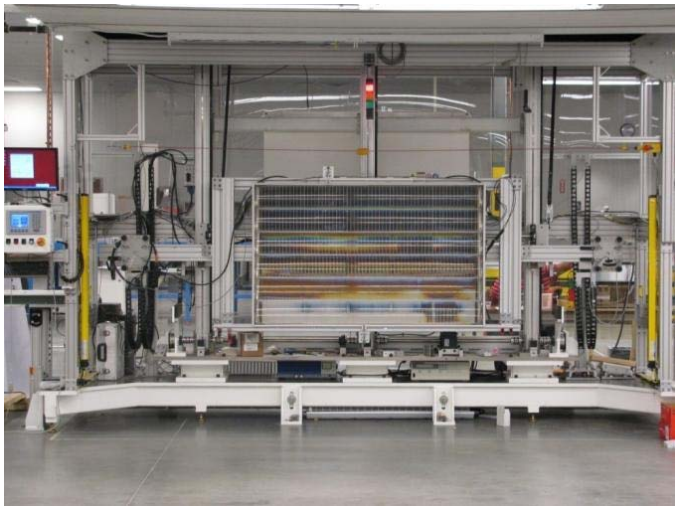


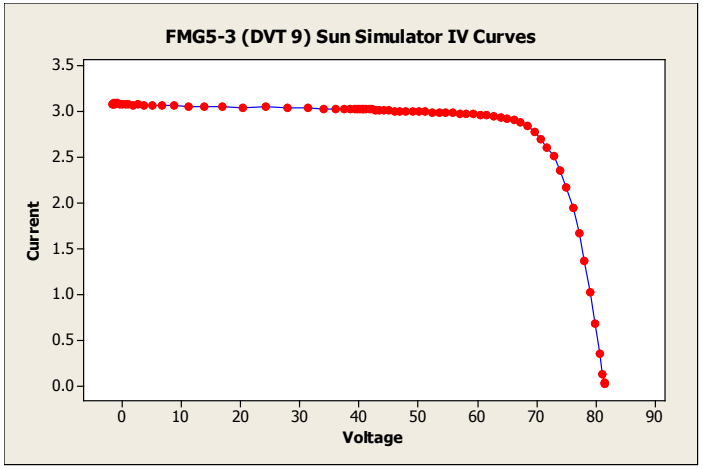
Cell Testing

- Description: Uses an e-load to sweep an IV curve from Voc to Isc under concentration.
- Purpose: To match cells in a receiver by ILoad. This will ensure max power, and prevent any one cell from limiting the series current.
- Concentration:
  - Flash intensity is set to
    - Flash concentration = Geometric Concentration ÷ Cell Width x gridline pitch ÷ bare silicon width between gridlines
  - Light level is calibrated to an NREL standard reference cell
- Common failure modes:
  - Shunting, cracked cells

World's Largest Sun Simulator

Sun Simulator with ThermaVolt II Module



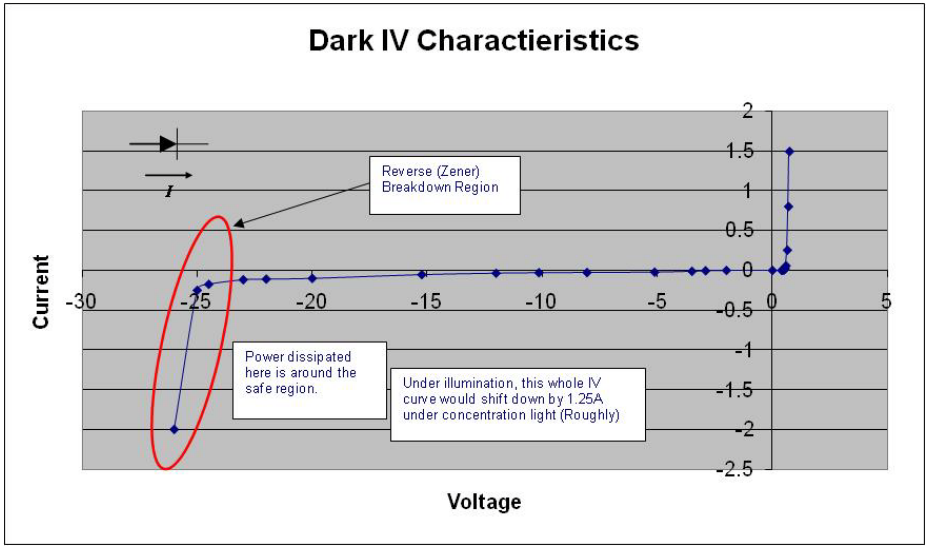


Sun Simulator IV Curve

- Description: Same as cell tester, but 110' Long, twice the light output, and capable of testing 12'x 3' CPV modules with 1 sun over full aperture.
- Purpose: Measure the performance of a module, without having to test outdoors.
- Simulating the Sun:
  - The Sun tunnel is set to 110' limiting all incident light angles at the CPV lens down to 3° for the 12' modules and 1.5° for the 5' modules.
  - Intensity is calibrated back to an NREL standard Reference cell
  - Uniformity: Spacial, Temporal, and Angular uniformity are considered to achieve Class B simulation.

Dark IV

Diode Characteristics

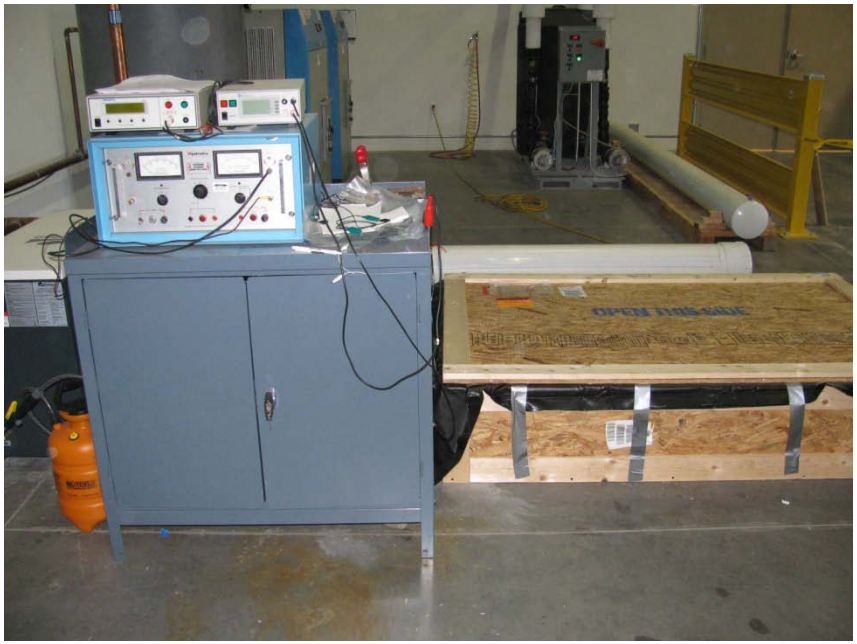


Dark IV Testing

- Description: Measures the series resistance through the cells and diodes. Applies 1.25*Isc through the cells and diodes and measures the voltage drop across the receiver or module.
- Purpose: Would identify defects such as broken wire bonds, broken cells, bad electrical contacts or connectors, etc.

Dry and Wet Hi-Pot

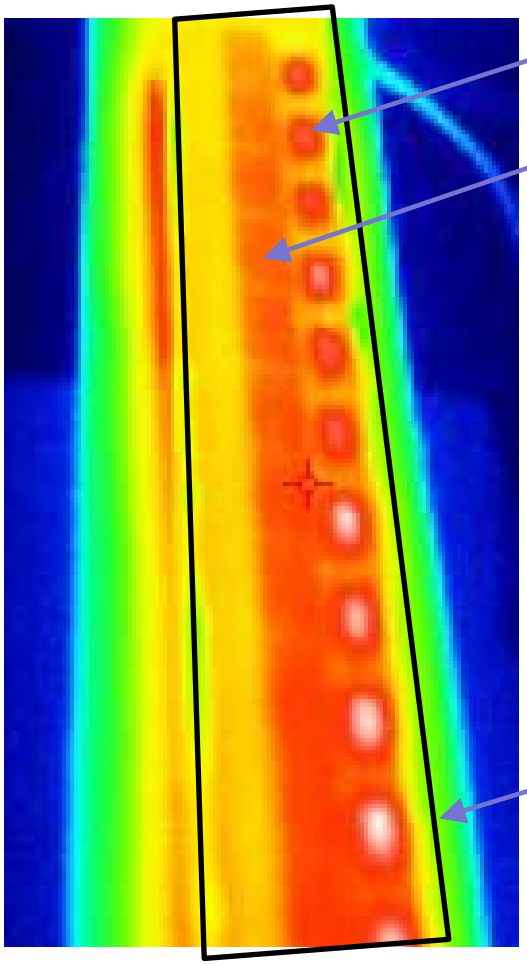
Dry and Wet Hi-Pot Station



Dielectric Testing

- Description: Test the electrical insulation of the module and receivers by applying a voltage between the electrical circuit and the ground plane.
- Purpose: Useful for identifying defects in the encapsulation, dielectric layers, wire insulation, etc.

Thermal Testing

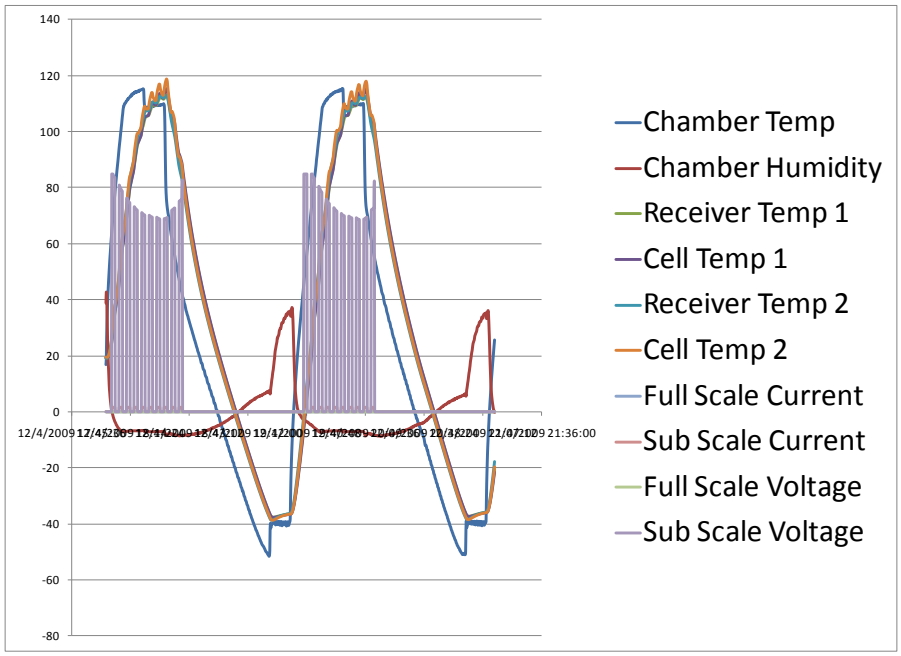


Thermal Imaging
Description: Infrared images are taken to look for hot spots of both the cell and diode with current flowing through them.

Purpose: Useful for identifying defects such as thermal bonding issues, open cells or diodes, delamination.

Sequence A: Thermal Cycling

Thermal Cycle Profile

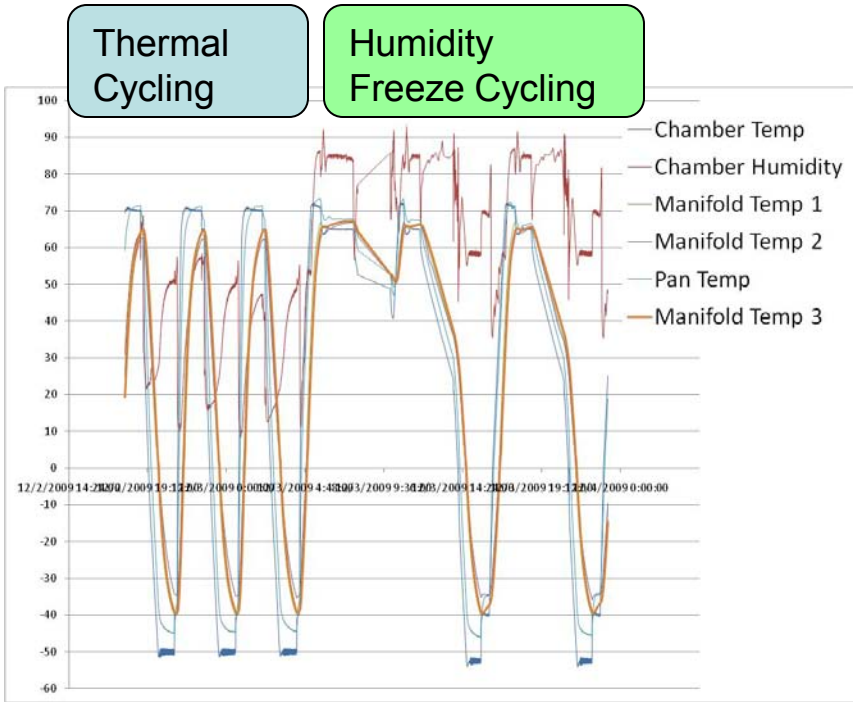


Thermal Cycling

- Description: An accelerated stress test. It cycles receivers in a 110°C to -40°C environment, for a total of 400 cycles. During the hot cycle (>25°C) a forward current (1.25*Isc) is applied off and on through the cells to further heat up the receivers.
- Purpose: To stress the design, and identify failures such as dielectric breakdown, loss of electrical continuity, cracking, delamination, etc.

Sequence B: Humidity Freeze

Humidity Freeze Profile



Humidity Freeze Test

- Description: An accelerated stress test consisting of a series of 400 thermal cycles (65°C to -40°C) followed by forty 24 hour long cycles in a high humidity environment. The Humidity Freeze profile consist of a 20 hour soak in a 65°C and 85% Relative Humidity followed by a 4 hour cycle at -40°C.
- Purpose: To stress the design and identify failures such as corrosion, loss of electrical continuity, shorting, cracking, delamination, etc.

Outdoor Testing

Outdoor Test Setup

Outdoor Testing

- Description: Measure electrical and thermal efficiency in real environment, and test the design against real world conditions per below.
- Purpose: To test the safety and performance of the modules, tests include: Beam Walk Off Test, Off Axis Beam Test, Material Temperature test, Dry Receiver Test, Water Spray, and Ground Path Continuity Test.

Other Test

Hail Test – Passed

Flame Test – Passed