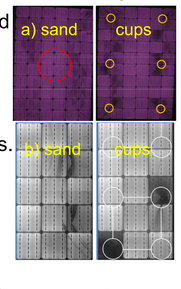
A Better Way to Bend:
Vacuum and Air Pressure for Mechanical Load Testing of Solar Panels

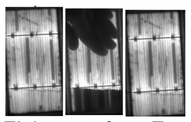
Andrew M. Gabor, Rob Janoch, Andrew Anselmo
BRIGHTSPOT AUTOMATION LLC, WESTFORD, MA 01886, USA

1. Background/Motivation

- Mechanical load testing is important to probe the durability of modules with respect to cell cracking, interconnect wire fatigue, solder bond integrity, and other concerns
  - IEC 61215 requires static load testing 1hour/side (3 times) at 2400Pa +/- 120Pa
  - Cyclic (dynamic) load testing is defined by IEC DTS 62782 as 1000Pa +/- 100Pa in both directions at 3-7 cycles/min for 1000 cycles
  - Faster and longer cyclic loading or loading at higher levels is often implemented by R&D groups for accelerated durability testing
- Point loading by the suction cup method can lead to excessive cell cracking under the suction cups, especially if they are spaced too far apart
- Prior work at Evergreen Solar showed that pre-existing cracks can be temporarily opened by applying light pressure to the front side
  - This allows visualization (EL) and quantification (IV) of the impact of these cracks were they to open up in the field
  - But the standard suction cup, air bladder, and sandbag methods block access to the front side for such characterization
- We have designed the *LoadSpot* tool to apply uniform pressure and to allow characterization from the front side by using the approach of vacuum/air-pressure applied to the rear side of the modules



EL images from a) Samsung[1] and b) Fraunhofer ISE[2] showing how suction cups load tools can introduce point loading that damages cells preferentially beneath the suction cup locations.

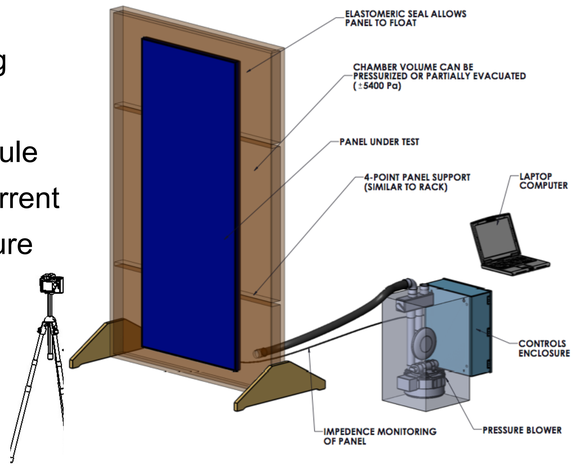


EL images from Evergreen Solar[3] demonstrating the opening and reclosing of cracks by applying light pressure on the glass

Load testing by a) Sand bags (Solarworld), b) air pressure bag (DNV-GL), c) vacuum cup system (PSE AG), and vacuum/air-pressure cavity (Jabil)

2. *LoadSpot* Design

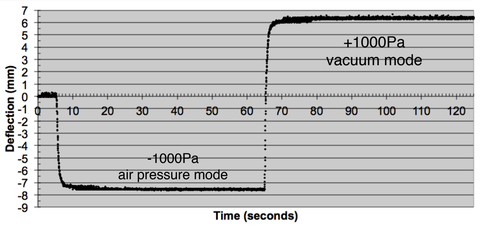
- The prototype *LoadSpot* tool was designed and built to:
  - Be easily adjustable for a wide range of module sizes (framed and unframed) and clamping hardware and clamping locations
  - Allow effective sealing of the rear vacuum/air-pressure cavity without applying significant forces on the module's edges that would restrict their movement
  - Apply > +/-2400Pa static loads
    - +5400Pa heavy snow-load goal
  - Apply cyclic loads at rates > 7 cycles/min
  - Allow completely open access to the front side for characterization and access to the rear-side J-box or cables
  - Apply forward voltage bias for EL testing
  - Monitor continuity of the circuit
  - Measure deflection in the center of module
  - Resistively heat module with forward current
  - Allow testing under controlled temperature
    - Temperature range to be determined

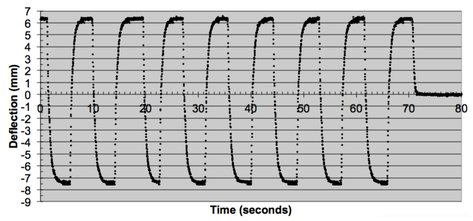


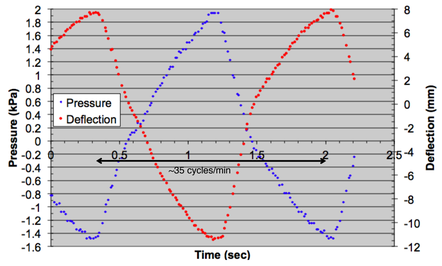
Simplified conceptual schematic of *LoadSpot* design

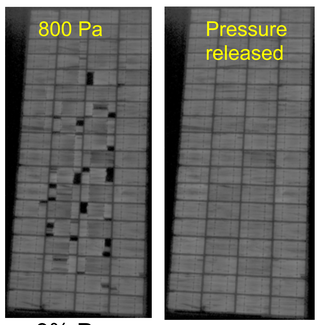
3. Prototype *LoadSpot* Data

- Manual actuation of the valve controlling rear-side vacuum/air-pressure shows:
  - Static tests at a fixed valve position indicate stable control of pressure and deflection even before implementation of feedback control
  - Static values in excess of +/-2400Pa have been achieved. However, a stronger blower is needed to reliably reach 5400Pa.
  - Flipping the valve between vacuum and air-pressure easily shows a cycling rate faster than the required 7 cycles/min
  - If no dwell is required at the peak pressure values, then we can achieve cycling rates > 35 cycles/min at pressures much higher than +/-1000 Pa









~9% Pmax degradation

- With application of vacuum from the rear side (800Pa front side pressure):
  - Pre-existing cracks can be opened up and imaged by EL
  - The difference in IV measurements between the crack-open and crack-closed states can be calculated to predict the potential future Pmax degradation in the field were these cracks to open up

4. Conclusions

- We have built a prototype mechanical load testing tool that has some advantages over traditional testing methods and tools in terms of pressure uniformity and the ability to perform IV and EL testing under load
- We have demonstrated a crack-opening test under low front-side loads that can serve as a quick predictor of potential module degradation in the field
  - The test is much quicker, easier, and non-destructive in comparison to using humidity-freeze and thermal cycling to "open up cracks" and thus R&D cycles can be performed more quickly at lower cost
  - By gradually increasing pressure, one can observe when/where cracks form to help optimize panel design and manufacturing[4]
- All load tests in IEC 61215 and IEC DTS 62782 can be performed
  - Cyclic loading can occur as fast as 35 cycles/min (0.58Hz) if no dwell is required
- The *LoadSpot* prototype design appears sound. Final market input is being collected for the commercial design, with shipments to commence by Q3 2016.

COMPARISON OF MECHANICAL LOADING METHODS

Factor	Sand bags	Suction Cups	Air bladder	Vacuum/ Air Pressure
Static test	Manual Flip	Auto	Manual Flip	Auto
Cyclic test	No	Yes	One direction	Yes
Point loading	No	Yes	No	No
Test with racking	Top static	Yes	Top static	No
Simultaneous EL/IV	No	No	No	Yes

5. References

[1] D. Baek, Presentations of the 2014 NREL Photovoltaic Module Reliability Workshop (Golden, CO, USA, 2014), Retrieved 15Jan2016 from www.nrel.gov/pv/performance_reliability/pvmrw_2014.html
[2] G. Mülhöfer, et. al., Proceedings 28th EUPVSEC (WIP, Paris, France, 2013) p. 2968
[3] A. M. Gabor, et. al., Proceedings 21st EUPVSEC (WIP , Dresden, Germany, 2006) p. 2042
[4] A. M. Gabor, et. al., to be published, Proceedings 43rd IEEE PVSC (Portland, OR, USA) 2016.