Qualification and Lifetime Testing Protocols for Gen II Back Contact Solar Cells/Modules

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Applied Materials

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Front Contact vs. Back Contact Technologies

- Current front contact module (Gen I) technology is highly reliable
  - Proven with accelerating aging results and field performance (30 years)
  - Most failure modes and mechanisms have been identified and are well understood

- Second Generation Back Contact (Gen II) Modules have:
  - New designs
  - New materials and material combinations
  - New methods of construction
  - **Potentially new failure mechanisms**

Adoption of Gen II Back Contact Modules requires proof of equal or better reliability than Gen I Front Contact Modules

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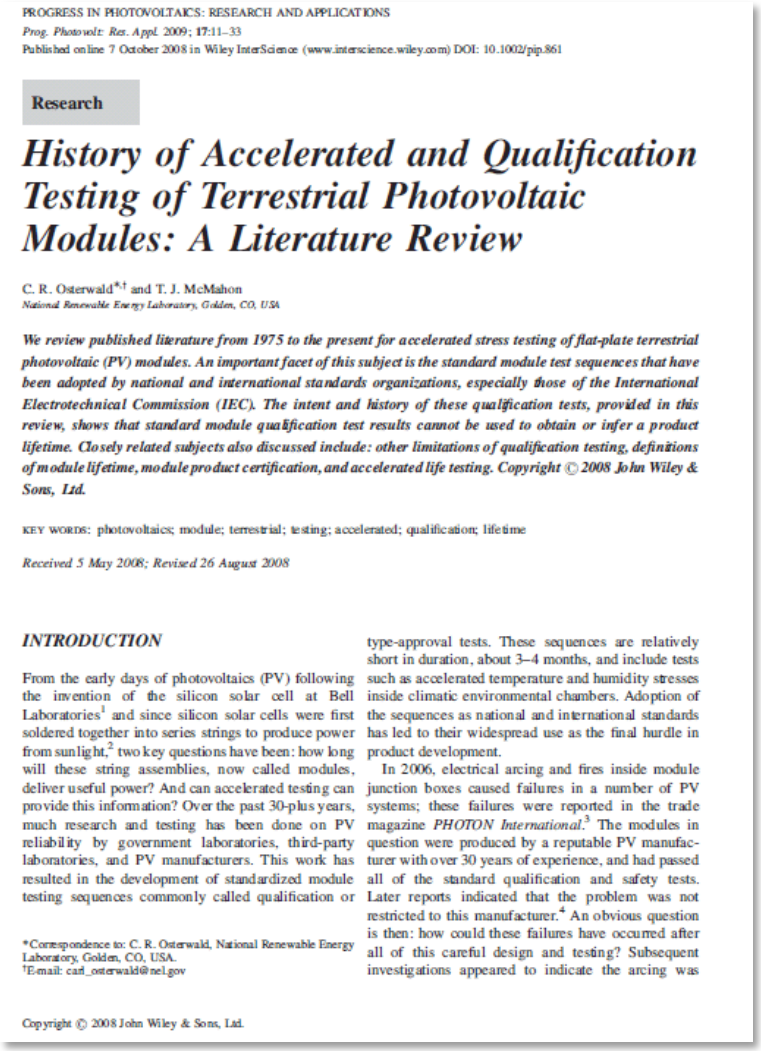
Gen I Front Contact Qualification is Proven

- Carl Osterwald and Tom McMahon from NREL published an excellent history of how the current set of accelerated and qualification tests were established[1]
- IEC 61646, 61730 and 61215 along with UL 1703 are the industry standards for certifying and baseline testing of modules
- Many manufacturers have extended testing beyond the 200 thermal cycles and 1000 hours of 85 C, 85% RH called for in the above standards to further demonstrate the reliability of their modules



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Research

History of Accelerated and Qualification Testing of Terrestrial Photovoltaic Modules: A Literature Review

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We review published literature from 1975 to the present for accelerated stress testing of flat-plate terrestrial photovoltaic (PV) modules. An important facet of this subject is the standard module test sequences that have been adopted by national and international standards organizations, especially those of the International Electrotechnical Commission (IEC). The intent and history of these qualification tests, provided in this review, shows that standard module qualification test results cannot be used to obtain or infer a product lifetime. Closely related subjects also discussed include: other limitations of qualification testing, definitions of module lifetime, module product certification, and accelerated life testing. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: photovoltaics; module; terrestrial; testing; accelerated; qualification; lifetime

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INTRODUCTION

From the early days of photovoltaics (PV) following the invention of the silicon solar cell at Bell Laboratories[1] and since silicon solar cells were first soldered together into series strings to produce power from sunlight,[2] two key questions have been: how long will these string assemblies, now called modules, deliver useful power? And can accelerated testing can provide this information? Over the past 30-plus years, much research and testing has been done on PV reliability by government laboratories, third-party laboratories, and PV manufacturers. This work has resulted in the development of standardized module testing sequences commonly called qualification or type-approval tests. These sequences are relatively short in duration, about 3–4 months, and include tests such as accelerated temperature and humidity stresses inside climatic environmental chambers. Adoption of the sequences as national and international standards has led to their widespread use as the final hurdle in product development.

In 2006, electrical arcing and fires inside module junction boxes caused failures in a number of PV systems; these failures were reported in the trade magazine *PHOTON International*.[3] The modules in question were produced by a reputable PV manufacturer with over 30 years of experience, and had passed all of the standard qualification and safety tests. Later reports indicated that the problem was not restricted to this manufacturer.[4] An obvious question is then: how could these failures have occurred after all of this careful design and testing? Subsequent investigations appeared to indicate the arcing was

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[1] History of Accelerated and qualification Testing of Terrestrial Photovoltaic Modules: A literature review, Progress in Photovolt: Re. Appl 2009

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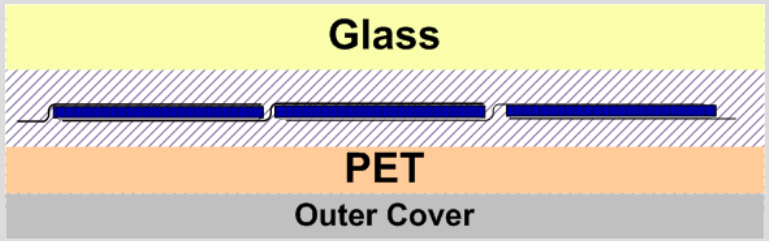
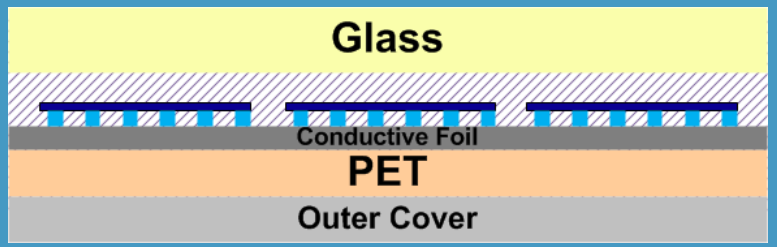
Front Contact is Different than Back Contact

Generation I Front Contact



- Flat Cu wire interconnects weaved from front to rear surface of adjacent cells requiring space between the cells for stress relief
- Aligned Cu interconnects on front and rear of cells produce balanced stress
- Soldered interconnects
- Permeable backsheet construction
- Industry standard EVA encapsulant

Generation II Back Contact



- Interconnects solely on the rear surface
- Reduced spacing between cells
- New materials and new interfaces
- Interconnects are no longer balanced
- Alternative circuit interconnects (electrically conductive adhesives, low temperature solder, etc.)

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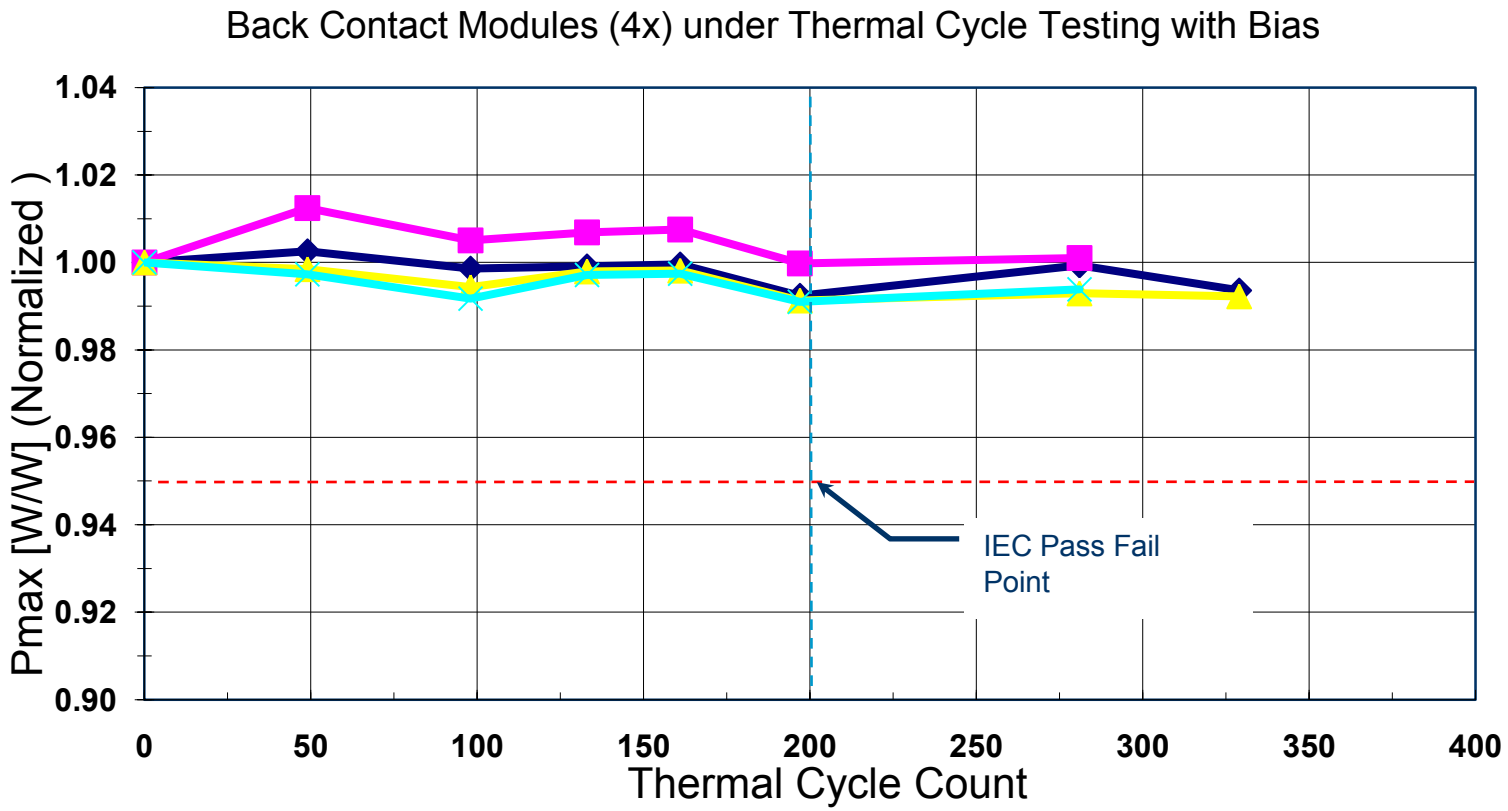
Gen II Back Contact Module Qualification

Current Status – Example 1



- An example of the use of extended testing to characterize reliability properties of new designs
- **Consistently passes industry standard tests, but is this sufficient?**

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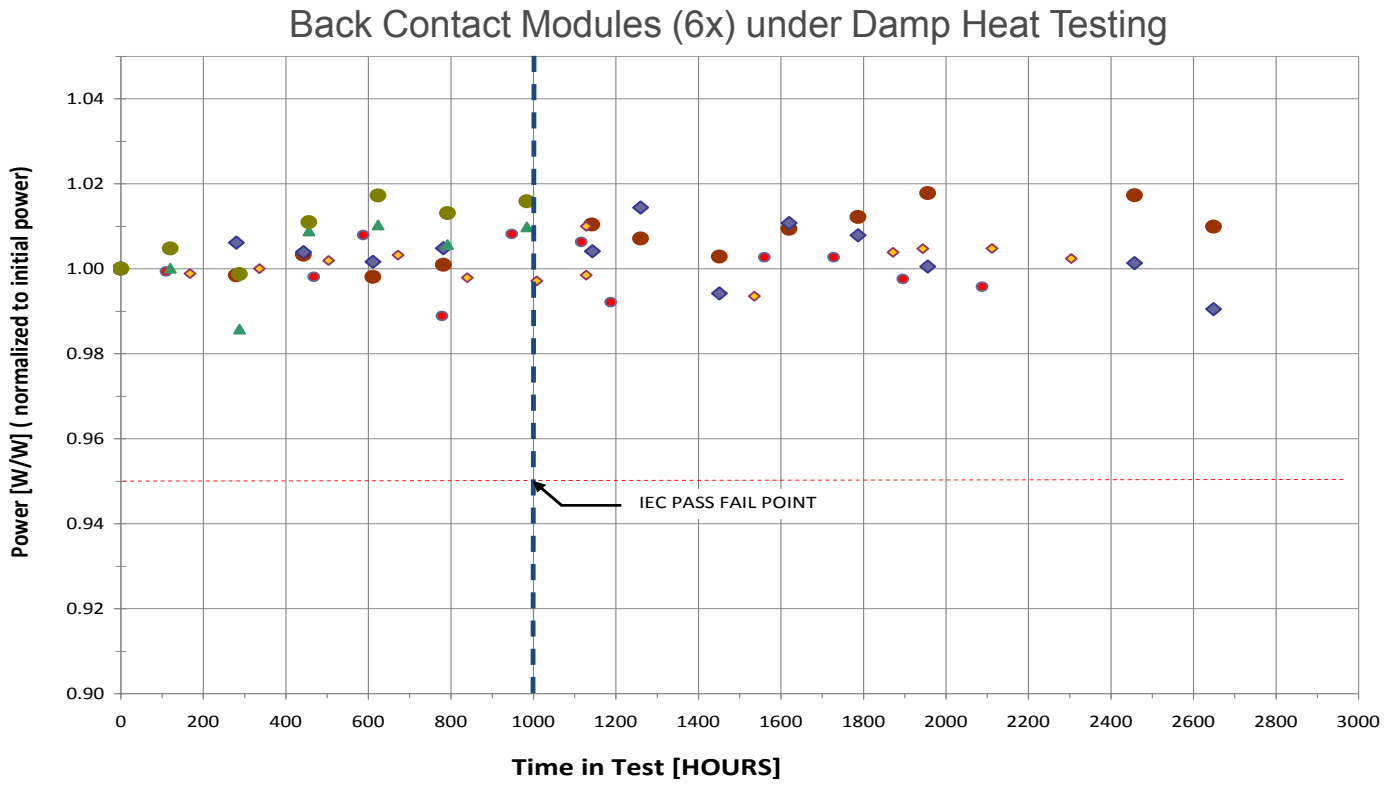
Gen II Back Contact Module Qualification

Current Status – Example 2



- An example of the use of extended testing to characterize reliability properties of new designs
- **Consistently passes industry standard tests, but is this sufficient?**

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Advancing Gen II Back Contact Technology

- Industry standard accelerated aging tests will detect common failure modes such as those in Gen I Front Contact modules

- **Collaboration** between material suppliers, module manufacturers and National Labs is required **to define and conduct accelerated testing** that is necessary to **prove reliability** of Gen II back contact modules **enabling** expedited market acceptance

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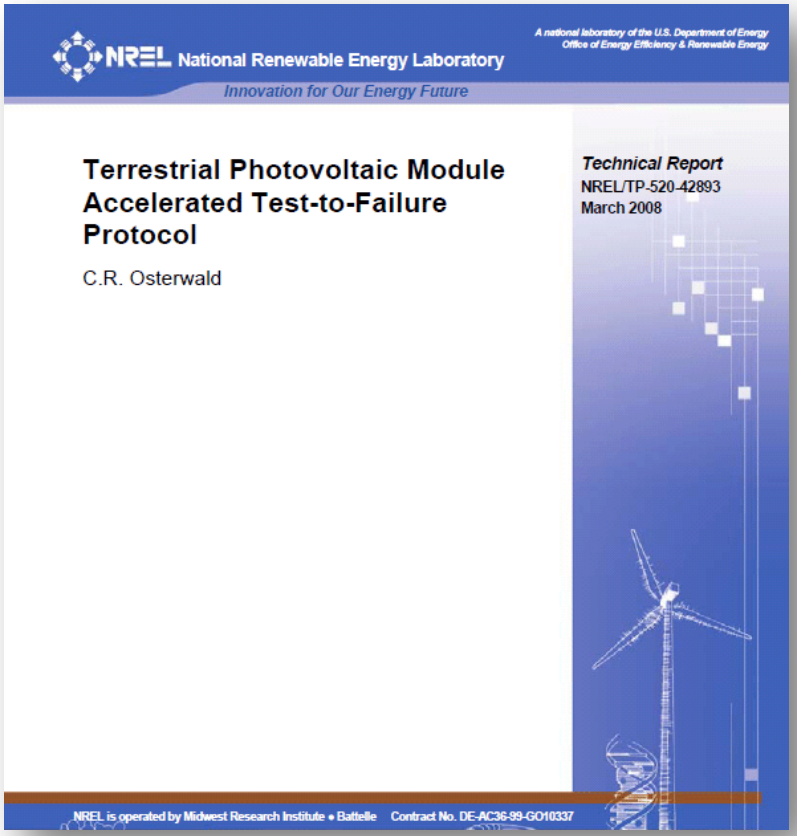
Approach – Exceed Front Contact Standards

- Our proposal is to use comparative testing that expands on current IEC 61215 standards to include protocols recommended by Carl Osterwald[2]
- A Gen I front contact module with a proven 25 year life will undergo selected accelerated tests side by side with Gen II back contact modules. This will reduce uncertainty and provide the required comparative measure
- Gen II back contact modules must perform as well or better than the conventional module under extended life time tests to failure



[2] **Terrestrial Photovoltaic Module Accelerated Test-to-Failure Protocol** C.R. Osterwald ,***Technical Report,*** **NREL/TP-520-42893 ,March 2008**

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Proposed Testing Protocols for Gen II Back Contact Modules

Recommended Test	Origin	Failure to be Detected
TC (-40 to +85 or 90ºC) cycle; 4x daily, under 1.25 I_{sc} forward bias; Test to Failure	IEC 61215	CTE mismatch failure, excessive heating due to poor interconnect bonding, soldering issues
HF (-40 to + 85ºC) cycle; 1x daily; Test to Failure	IEC 61215	Failure of bonds at surfaces
HF (-40 to + 85ºC) cycle; 1x daily; Test to Failure	IEC 61215	Failure of bonds at surfaces
Mechanical Load and Hail Test	IEC 61215	Mechanical integrity of module design
DH under 1000 volts; Test to Failure	New	Galvanic corrosion, yellowing, electro migration
DH 1000 followed by HF; Test to Failure	New	Failure of bonds at surfaces; moisture ingression

Additional Ideas are Welcome!

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Advantages

- This combination of extended industry standard test protocols with additional stresses of electric field on DH and current load in TC is likely to identify most of the failure modes
- By extending all protocols to be test to failure and comparing to the performance of a standard reference module provides confidence in the reliability performance of new module designs

Risks and Mitigations

- No method in any HALT approaches to reliability testing can guarantee that all failure modes will be found
- Early field testing is required to gain complete confidence that the majority of failure modes are found
- Reliability engineering and physics studies must also be conducted to analyze the reliability properties of designs

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Moving Forward

The solar industry and the National Labs, building on our experiences from the last 30 years, need to have a collaborative effort to define and conduct the accelerated testing required to prove the reliability of these Gen II back contact modules enabling expedited market acceptance.

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