PACT Module Design Acceptance Criteria (Industry)

Version 3

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Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Executive Summary

The mission of the PACT center is to develop performance and reliability testing protocols and measure outdoor performance of emerging photovoltaic module technologies (including perovskite, organic, and other novel PV modules. PACT defines a PV module as a weatherproof package containing multiple, interconnected solar cells that can be electrically connected to an external load. PACT will not test widely commercialized PV technologies, such as c-Si. PACT seeks partnerships with industry and academic partners that are producing modules for testing purposes. To ensure both safety and high-quality samples PACT publishes acceptance criteria to define the minimum characteristics of modules the center will accept for testing. These criteria help to ensure we are accepting technologies that are compatible with our technical facilities and testing equipment and that can transition to large scale commercial manufacturing.

Here we provide a quick reference guide and a more detailed appendix. Anyone interested in testing with PACT for the first time are encouraged to start by reaching out to Josh Stein (jsstein@sandia.gov) and Laura Schelhas (Laura.schelhas@nrel.gov) to discuss testing requirements.

Updates to the criteria are expected over the lifetime of the PACT center. When changes are made a new version will be published. Specific changes to the document will be outlined below.

Version Updates

Version 1.0 – Initial release

Version 2.0 – Simplified requirements

Version 3.0 – Further simplified the requirements and added module technologies other than perovskites.

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1. INTRODUCTION

For the PACT center to both develop testing protocols and be able to evaluate the state of emerging PV module technologies, PACT seeks modules for testing purposes. To ensure both safety and high-quality samples PACT publishes acceptance criteria to define the minimum design characteristics of modules the center will accept for testing. These criteria help to ensure we are accepting technologies that are compatible with our technical facilities and testing equipment and that can transition to large scale commercial manufacturing.

PACT may not accept all modules, even if they meet all the acceptance criteria due to limited resources and/or too many of a similar type, design, construction, or composition. In the event capacity limits the modules that can be accepted by the center, PACT leadership will review available modules and prioritize based on the programs needs and deliverables. We fully anticipate that these acceptance criteria will change over time in response to advances in the technology and testing capacity limitations of the PACT center.

2. DEFINITIONS

- **Module** - weatherproof package containing multiple, interconnected solar cells that can be electrically connected to an external load
- **Batch** - group of samples fabricated from identical materials using identical processes
- **MHP** – Metal Halide Perovskite
- **Industry samples –** Modules provided by industry partners. All PACT testing for industry samples shall be governed by a **PACT Test Plan** to be drafted prior to sending any samples. The test plan will be developed in meetings between each industry partner and PACT.

3. ARCHITECTURE AND TYPE

- Samples shall be modules with a weatherproof junction box connecting the module to electrical leads/wires.
    - NREL has developed a "Transition to Wire" (TTW) solution that can be used in cases that commercial junction boxes will not work. Please contact Laura Schelhas (Laura.Schelhas@nrel.gov) for more information.
    - When possible, please attach the TTW or junction box to the **front side of the module** to allow the module to lie flat on a thermal chuck for initial indoor testing.
- Solar cell technology type shall be disclosed by the supplier.

Note: There is no requirement as to number of absorbers, number of junctions per cell, or bifaciality. However, submission of bifacial modules shall be arranged in advance because they may require special testing and mounting considerations.

4. CHEMICAL COMPOSITION

Please provide the specific chemical composition of the module upon submittal to the PACT center.

Note: at this stage of the program there is no restriction, limitation, or guidelines for module chemical composition.

5. BATCHES

- Samples shall be delivered in groups of at least four samples from the same batch for each test that will be performed by the PACT center. It is encouraged but not required that additional samples be delivered from the same batch for development and validation of preconditioning protocols for measuring performance.
- Samples that have been subjected to accelerated testing prior to arriving at PACT shall not be counted in the sample totals per batch.

6. MECHANICAL REQUIREMENTS

6.1. Shape, Size, and Labeling

Samples shall be rectangular.

- Additional requirements:
    - Detailed descriptions of physical dimensions shall be shared with the PACT prior to sending samples.
    - Labels indicating sample IDs and other information shall be placed on the rear side of the modules. PACT will add labels with PACT IDs and other tracking information. It is important that all samples are labeled before sending to PACT so that test results can be compared with tests run by the manufacturer.

6.2. Designated area

- The designated area for use in estimating efficiency will be defined by a single rectangle that encompasses active cells in the module.
- It is strongly recommended that module suppliers attach their own masking so that an appropriate aperture area can be measured.
- PACT may apply an aperture during testing to ensure that efficiency measurements do not include extraneous sources of light (e.g., from the glass edges).
- We do not have a strict requirement of a minimum acceptable “active“ area but will prioritize devices with designated areas greater than 100 cm^2.

6.3. Packaging

- Modules shall ideally pass a wet leakage current test (IEC 61215-2 MQT 15). This test subjects the sample to at least 500V of potential while the module is shorted and submerged in a water bath to test the insulation of the package and junction box.
- Samples using identical packaging designs that have been shown to pass a wet leakage test may be tested at PACT without passing the test.

6.4. Wires and connectors

Insulated copper wires shall be included to connect samples to an external load.

- Conductors shall be suitable for safely carrying the maximum current produced by the module.
- Insulation shall be suitable for safely carrying the maximum voltage produced by the module.
- Wire shall be listed and labeled for outdoor PV use.
- Wire shall be no smaller than 20 AWG and no larger than 14 AWG.
- Wire length from the module shall be long enough to allow flexibility for installation and testing. PACT recommends wire length of 3m, if possible. Length shall be specified and agreed upon in the **PACT Test Plan**.
- PLEASE ensure accurate labeling of polarity – we have received numerous modules with polarity labeled incorrectly.

- PACT has standardized on using four wire Amphenol AT Series connectors and MC-4 connectors. Please contact PACT with information about connectors and wire lengths before sending modules for testing.

6.5. Rigidity

- Samples shall be rigid enough that they can be safely mounted by attaching only to the frame or edge of the module.
- Flexible modules shall be delivered to PACT mounted on a rigid substrate to allow mounting.
    - If temperature monitoring is important for testing of flexible modules, at least two thermocouples shall be attached to the rear surface of the module prior to mounting to rigid substrate. These details shall be included and agreed upon in the **PACT Test Plan**.
- Vendor to provide module mounting solution.

7. ELECTRICAL REQUIREMENTS

- While PACT does not have a minimum aperture efficiency, we prioritize modules with higher efficiencies when testing space is limited.
- No exposed parts shall be electrically connected to the internal module circuit, other than the distal ends of wires.
- Expected electrical characteristics (Voc, Isc, Vmp, Imp, etc.) of samples shall be documented in the **PACT Test Plan** to ensure that PACT has the hardware to monitor the performance of the modules.

8. OTHER INFORMATION THAT MAY BE REQUIRED FOR SOME SERVICES (FOLLOWING APPROVED NDA)

- Please provide a full bill of materials (BOM). The BOM should include the part name, part number or code, and part count.
- Please provide description or documentation of manufacturing processes being used to produce the module.
- If the module is being manufactured, please provide current monthly capacity.

9. FINAL NOTE

These acceptance criteria are meant to answer common questions about what PACT will accept. Please reach out to PACT management (Joshua Stein (jsstein@sandia.gov) and Laura Schelhas (Laura.Schelhas@nrel.gov) if you would like to test modules at PACT. These meetings are critical for ensuring a successful testing experience.

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