

21080 Test Report:

IEC TS 63209-1 Extended Stress Testing on M390-D1FB Modules Produced by Mitrex

Report Number: 21080-PR-E-001
Report Date: 2022-11-23
Test Period: 2022-02-07 to 2022-11-18
Project ID: 21080 (CFV), 000477 (Customer PO)
Customer: Hadi Khatibzadehazad / Mitrex
41 Racine Rd
Etobicoke, Ontario M9W 2Z4
Canada

| Report Prepared by: | Report Reviewed by: | Report Approved by: |
|---------------------|---------------------|---------------------|
| | | |

Project Summary

CFV Labs conducted extended reliability testing on twelve **M390-D1FB** modules produced by **Mitrex** per IEC TS 63209-1:2021 Extended Stress Testing. This protocol consists of five test legs: Thermal Cycling, Mechanical Degradation, UV Backsheet Stress, Humidity, and Potential Induced Degradation.

All modules were subjected to MQT 19 Stabilization, performance measurements, and safety tests prior to stress testing. The modules were then subjected to the following stresses based on test leg:

Control Module Measurements: One control module, taken from the sample set that was provided for testing, was stabilized and measured each time test modules were. A repeatability of $\pm 0.45\%$, which is the standard deviation ($k=2$) of Pmp of all control module measurements following stabilization, was adopted for this project.

Thermal Fatigue: two modules experienced three rounds of TC200 for a total thermal cycling dose of 600 cycles. The average performance change following testing was -5.93% . The modules passed all initial, interim, and final visual inspections and safety tests.

Mechanical Stress: One module was subjected to SMLT followed by DMLT, TC50 and HF10. A second module, used as a mechanical degradation reference, skipped SMLT, but was subjected to all other tests. The performance change following testing was -11.89% and -5.56% for the SMLT and SMLT-Reference modules respectively. The modules passed all initial, interim, and final visual inspections and safety tests.

Sequential Testing Including UV Stress to Module Back-side: One module was subjected to DH200, followed by (UV60 > TC50 > HF10) repeated three times for a total dose of 180 kWh/m² of UV exposure, 150 thermal cycles and 30 humidity/freeze cycles. This is a backsheet specific test leg, so performance was not measured for degradation. The module tested *passed* all initial, interim, and final visual inspections and safety tests.

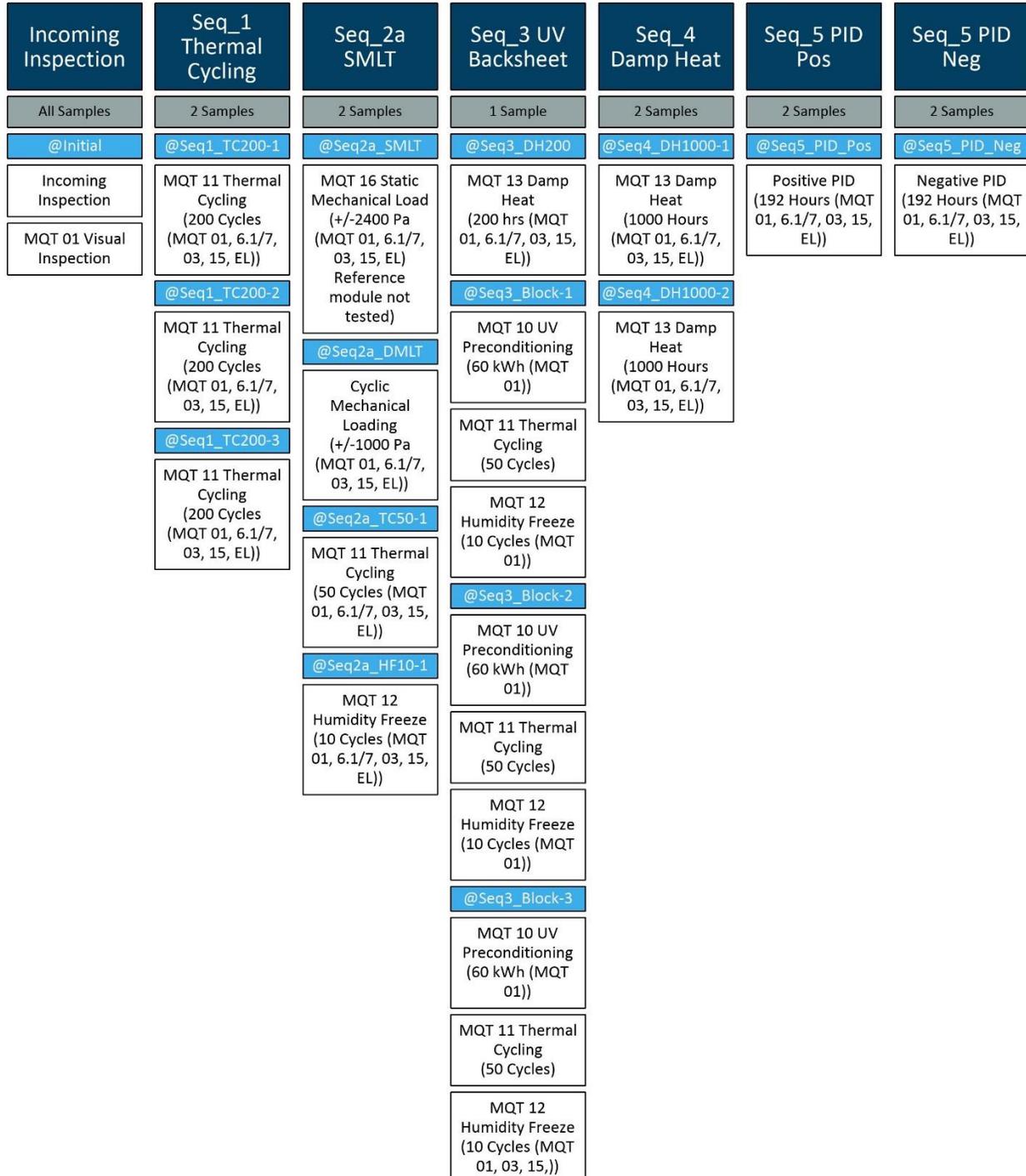
Damp Heat: Two modules experienced two rounds of DH1000 for a total damp heat dose of 2000 hours. The average performance change following testing was -4.70% . The modules passed all initial, interim, and final visual inspections and safety tests.

Potential Induced Degradation (PID): Four modules experienced one round of 192 hours of PID testing, two in the positive bias configuration, two in the negative bias configuration. The average performance change following testing was -3.05% and -47.91% in the positive and negative bias configuration respectively. The modules passed all initial, interim, and final visual inspections and safety tests.

This report is the summary report, which covers the following sub-reports: *21080A-PR-E-001 Sequence 1 Thermal Cycling Test Report, 21080B-PR-E-001 Sequence 2 Mechanical Stress Test Report, 21080C-PR-E-001 Sequence 3 Mechanical Stress Test Report, 21080D-PR-E-001 Sequence 4 Damp Heat Test Report, and 21080E-PR-E-001 Sequence 5 Potential Induced Degradation Test Report.*

Project Test Flow

The figure below shows the overall test flow for this project.



Test Flow Assignment

The modules utilized for this testing were supplied by the customer after they were inspected and sampled by PI Berlin for CFV Labs. The report, *CFV21080 Mitrex sample witness report 20220121_R2*, was provided separately to the customer.

These modules were free of obvious defects under visual inspection and electroluminescence imaging. The test flow assignment for each of the modules is provided in the table below. The modules were subjected to the test legs in the order listed.

| Module ID | Serial Number | Test Leg(s) | Notes |
|-----------|---------------|--|-------|
| 21080-001 | MIT21A04828 | Incoming Inspection | - |
| 21080-002 | MIT21A04827 | Incoming Inspection, Seq_Z Control | - |
| 21080-003 | MIT21A04820 | Incoming Inspection, Seq_1 Thermal Cycling | - |
| 21080-004 | MIT22A00019 | Incoming Inspection, Seq3_UV Backsheet | - |
| 21080-005 | MIT22A00020 | Incoming Inspection, Seq_2a SMLT | - |
| 21080-006 | MIT22A00023 | Incoming Inspection | - |
| 21080-007 | MIT22A00022 | Incoming Inspection | - |
| 21080-008 | MIT22A00026 | Incoming Inspection, Seq_1 Thermal Cycling | - |
| 21080-009 | MIT21A04856 | Incoming Inspection, Seq_2b SMLT-Reference | - |
| 21080-010 | MIT21A04876 | Incoming Inspection, Seq_4 Damp Heat | - |
| 21080-011 | MIT21A04883 | Incoming Inspection | - |
| 21080-012 | MIT21A04880 | Incoming Inspection | - |
| 21080-013 | MIT22A00010 | Incoming Inspection, Seq_4 Damp Heat | - |
| 21080-014 | MIT22A00009 | Incoming Inspection, Seq_5 PID_Pos | - |
| 21080-015 | MIT22A00008 | Incoming Inspection | - |
| 21080-016 | MIT22A00003 | Incoming Inspection | - |
| 21080-017 | MIT22A00002 | Incoming Inspection | - |
| 21080-018 | MIT22A00005 | Incoming Inspection | - |
| 21080-019 | MIT21A04888 | Incoming Inspection | - |
| 21080-020 | MIT21A04872 | Incoming Inspection, Seq_5 PID_Pos | - |
| 21080-021 | MIT21A04871 | Incoming Inspection, Seq_5 PID_Neg | - |
| 21080-022 | MIT21A04869 | Incoming Inspection | - |
| 21080-023 | MIT21A04849 | Incoming Inspection | - |
| 21080-024 | MIT21A04840 | Incoming Inspection | - |
| 21080-025 | MIT21A04822 | Incoming Inspection, Seq_5 PID_Neg | - |
| 21080-026 | MIT21A04825 | Incoming Inspection | - |
| 21080-027 | MIT21A04833 | Incoming Inspection | - |
| 21080-028 | MIT21A04834 | Incoming Inspection | - |
| 21080-029 | MIT21A04829 | Incoming Inspection | - |
| 21080-030 | MIT21A04824 | Incoming Inspection | - |

Sample Information

Sample Dimensions

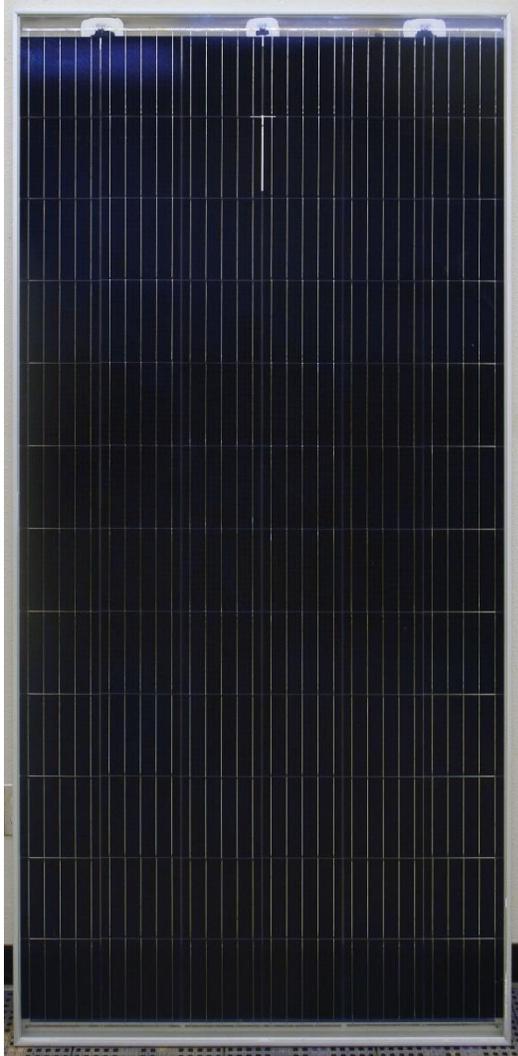
| Module Type | Length [m] | Width [m] | Thickness [mm] |
|-------------|------------|-----------|----------------|
| M390-D1FB | 2.03 | 0.99 | 40 |

Sample Nameplate Values

| Module Type | Isc [A] | Voc [V] | Imp [A] | Vmp [V] | Pmp [W] | Max Sys Volt [V] | Fuse Rating [A] |
|-------------|---------|---------|---------|---------|---------|------------------|-----------------|
| M390-D1FB | 9.76 | 47.3 | 9.29 | 42.0 | 390 | 1000 | 20 |

Sample Type Images

Module Type: M390-D1FB





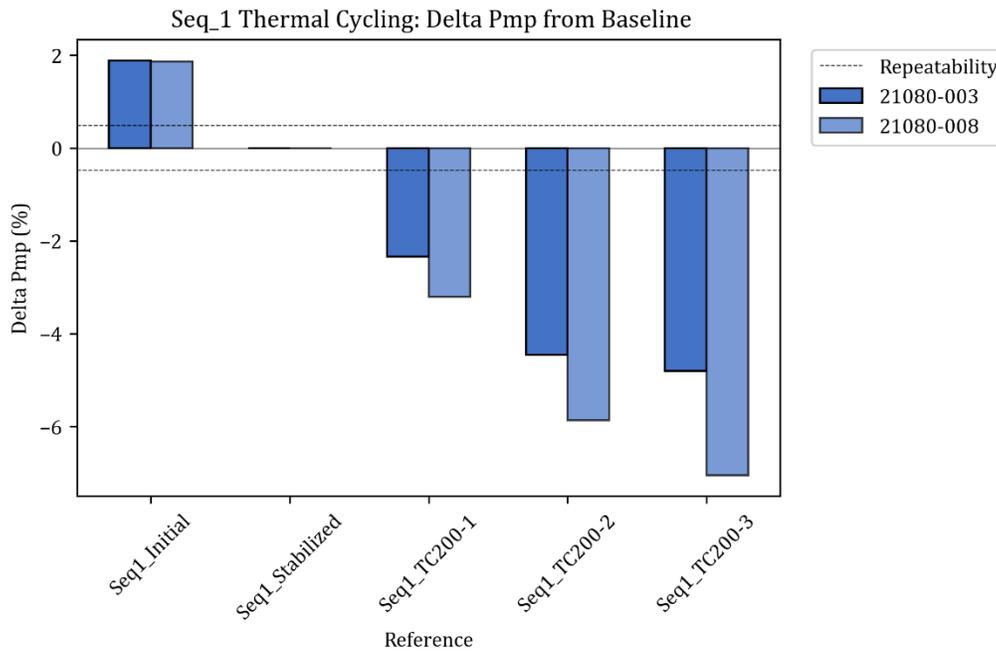
Results: Test Leg – Incoming Inspection

An incoming inspection report is provided separately to the customer. No issues were observed during the incoming inspection.

Results: Test Leg – Seq_1 Thermal Cycling

Summary of Results – Performance at STC and Safety Testing

The plots below show the Performance at STC measurement results as a change from Baseline (Stabilized).



Note: Repeatability was calculated as the standard deviation (k=2) of the control module results measured during this project following MQT 19 stabilization. The control modules were taken from the modules provided for this project.

The tables below show the Performance at STC, Visual Inspection, and safety testing results per module. When required, more detail is provided in the section referenced in the “Notes” field.

A module’s ΔPmp (%) was calculated as the change from the *stabilized* value.

Module: 21080-003

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|--------------|-------------------|-------------|------------|
| Initial | 9.964 | 49.17 | 9.455 | 40.40 | 381.97 | +1.89 | pass | pass | pass |
| Stabilized | 9.953 | 49.10 | 9.334 | 40.17 | 374.89 | - | pass | pass | pass |
| TC200-1 | 9.937 | 48.95 | 9.315 | 39.30 | 366.12 | -2.34 | pass | pass | pass |
| TC200-2 | 9.882 | 48.91 | 9.177 | 39.03 | 358.20 | -4.45 | pass | pass | pass |
| TC200-3 | 9.909 | 49.03 | 9.182 | 38.87 | 356.91 | -4.80 | pass | pass | pass |

Notes:

Module: 21080-008

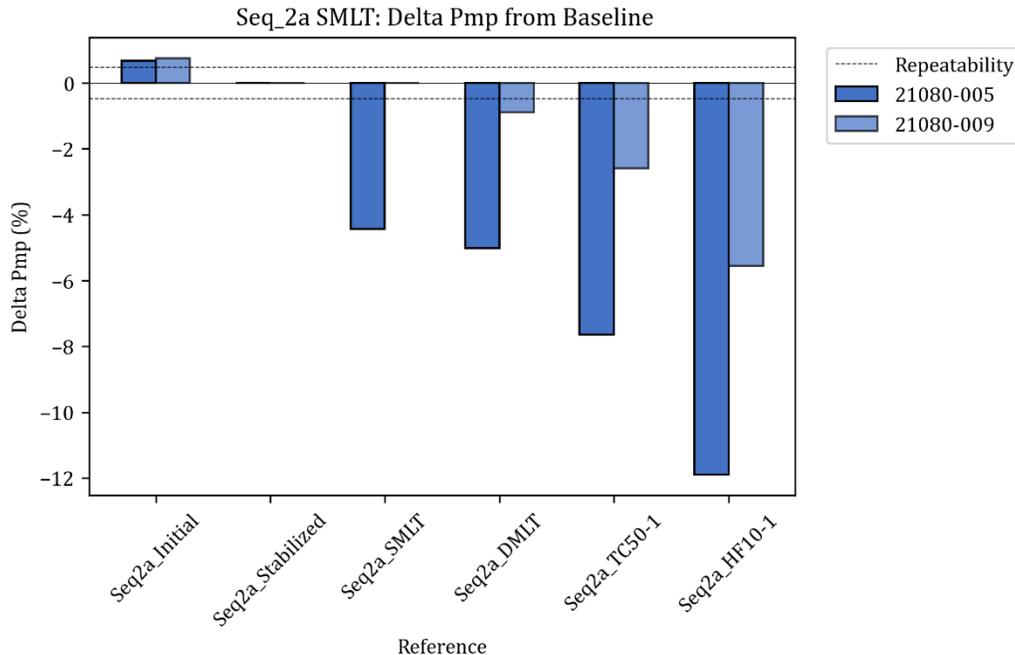
| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|--------------|-------------------|-------------|------------|
| Initial | 9.983 | 49.18 | 9.508 | 40.68 | 386.76 | 1.86 | pass | pass | pass |
| Stabilized | 9.984 | 49.08 | 9.447 | 40.19 | 379.71 | - | pass | pass | pass |
| TC200-1 | 9.936 | 48.93 | 9.365 | 39.25 | 367.52 | -3.21 | pass | pass | pass |
| TC200-2 | 9.851 | 48.97 | 9.186 | 38.91 | 357.41 | -5.87 | pass | pass | pass |
| TC200-3 | 9.923 | 49.02 | 9.198 | 38.37 | 352.93 | -7.05 | pass | pass | pass |

Notes:

Results: Test Leg – Seq_2 Mechanical Stress - SMLT

Summary of Results – Performance at STC and Safety Testing

The plots below show the Performance at STC measurement results as a change from Baseline (Stabilized).



Note: Repeatability was calculated as the standard deviation (k=2) of the control module results measured during this project following MQT 19 stabilization. The control modules were taken from the modules provided for this project.

The tables below show the Performance at STC, Visual Inspection, and safety testing results per module. When required, more detail is provided in the section referenced in the “Notes” field.

A module’s ΔPmp (%) was calculated as the change from the *stabilized* value.

Module: 21080-005

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 9.971 | 49.15 | 9.478 | 40.29 | 381.90 | +0.67 | pass | pass | pass |
| Stabilized | 9.959 | 49.14 | 9.455 | 40.12 | 379.37 | - | pass | pass | pass |
| SMLT | 9.937 | 48.90 | 9.107 | 39.81 | 362.55 | -4.43 | pass | pass | pass |
| DMLT | 9.941 | 48.91 | 9.051 | 39.81 | 360.37 | -5.01 | pass | pass | pass |
| TC50 | 9.965 | 48.82 | 8.942 | 39.18 | 350.37 | -7.64 | pass | pass | pass |
| HF10 | 9.814 | 48.81 | 8.631 | 38.73 | 334.26 | -11.89 | pass | pass | pass |

Notes:

Module: 21080-009 (Mechanical degradation reference module)

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|--------------|-------------------|-------------|------------|
| Initial | 10.002 | 49.15 | 9.468 | 40.29 | 381.46 | +0.75 | pass | pass | pass |
| Stabilized | 9.975 | 49.12 | 9.439 | 40.11 | 378.61 | - | pass | pass | pass |
| SMLT | - | - | - | - | - | - | - | - | - |
| DMLT | 9.956 | 49.04 | 9.377 | 40.02 | 375.23 | -0.89 | pass | pass | pass |
| TC50 | 9.983 | 48.94 | 9.321 | 39.56 | 368.77 | -2.60 | pass | pass | pass |
| HF10 | 9.842 | 48.97 | 9.076 | 39.40 | 357.57 | -5.56 | pass | pass | pass |

Notes: As the mechanical degradation reference, this module was not subjected to SMLT in the test flow

Results: Test Leg – Seq_3_UV_Backsheet

Summary of Results – Performance at STC and Safety Testing

The tables below show the Performance at STC, Visual Inspection, and safety testing results per module. When required, more detail is provided in the section referenced in the “Notes” field.

A module’s ΔP_{mp} (%) was calculated as the change from the *stabilized* value.

Module: 21080-004

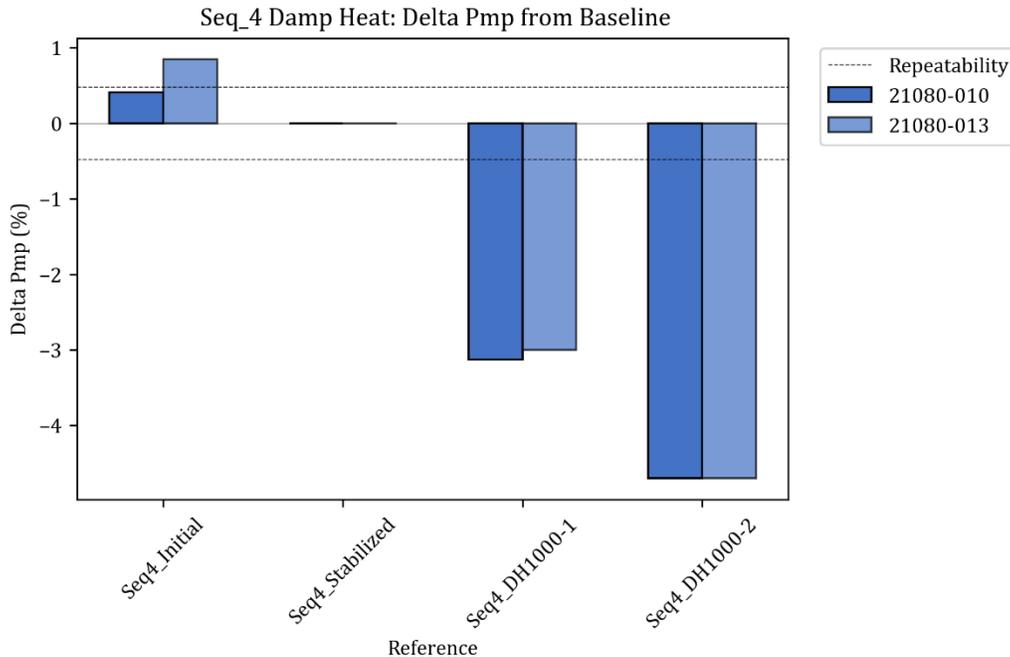
| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔP_{mp} (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|---------------------|-------------------|-------------|------------|
| Initial | 9.987 | 49.15 | 9.489 | 40.29 | 382.29 | +0.84 | pass | pass | pass |
| Stabilized | 9.972 | 49.11 | 9.448 | 40.12 | 379.09 | - | pass | pass | pass |
| DH200 | - | - | - | - | - | - | pass | - | - |
| HF10-1 | - | - | - | - | - | - | pass | - | - |
| HF10-2 | - | - | - | - | - | - | pass | - | - |
| HF10-3 | - | - | - | - | - | - | pass | pass | pass |

Notes: This test leg is a backsheet test, so performance was not conducted for the majority of the project. Visual inspection of the module backsheet was conducted using 10x magnification.

Results: Test Leg – Seq_4 Damp Heat

Summary of Results – Performance at STC and Safety Testing

The plots below show the Performance at STC measurement results as a change from Baseline (Stabilized).



Note: Repeatability was calculated as the standard deviation (k=2) of the control module results measured during this project following MQT 19 stabilization. The control modules were taken from the modules provided for this project.

The tables below show the Performance at STC, Visual Inspection, and safety testing results per module. When required, more detail is provided in the section referenced in the “Notes” field.

A module’s ΔPmp (%) was calculated as the change from the *stabilized* value.

Module: 21080-010

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 9.968 | 49.17 | 9.458 | 40.37 | 381.83 | +0.41 | pass | pass | pass |
| Stabilized | 9.977 | 49.08 | 9.437 | 40.30 | 380.28 | - | pass | pass | pass |
| DH1000-1 | 9.756 | 48.90 | 9.227 | 39.92 | 368.38 | -3.13 | pass | pass | pass |
| DH1000-2 | 9.699 | 49.00 | 9.131 | 39.69 | 362.39 | -4.70 | pass | pass | pass |

Notes:

Module: 21080-013

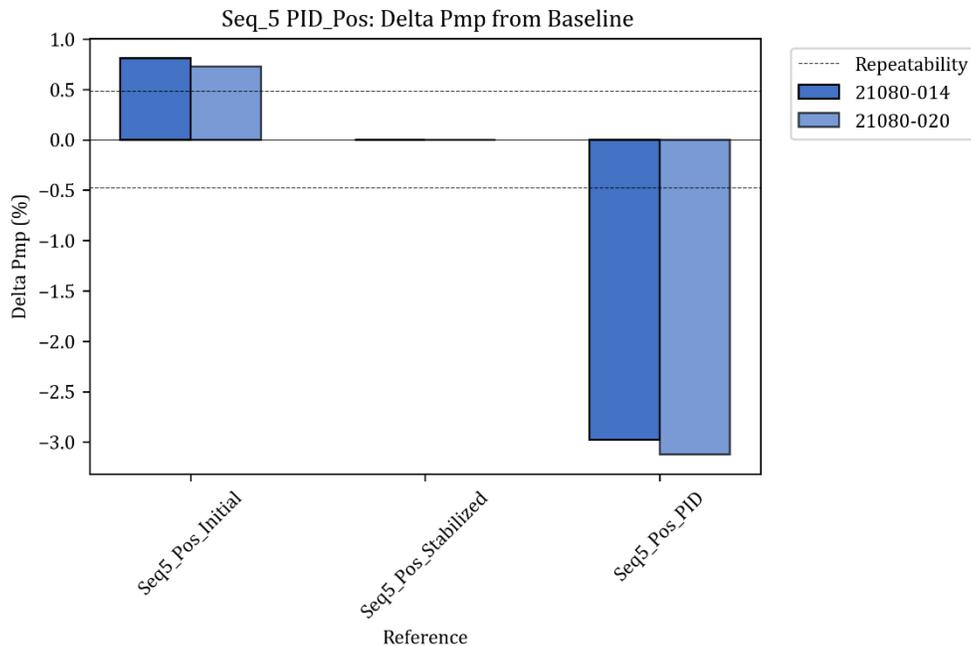
| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | Δ Pmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 9.991 | 49.22 | 9.472 | 40.45 | 383.12 | +0.85 | pass | pass | pass |
| Stabilized | 9.976 | 49.12 | 9.423 | 40.32 | 379.91 | - | pass | pass | pass |
| DH1000-1 | 9.780 | 48.87 | 9.241 | 39.88 | 368.52 | -3.00 | pass | pass | pass |
| DH1000-2 | 9.723 | 48.92 | 9.138 | 39.62 | 362.07 | -4.70 | pass | pass | pass |

Notes:

Results: Test Leg – Seq_5 Potential-Induced Degradation (PID) Testing (Positive Bias Configuration)

Summary of Results – Performance at STC and Safety Testing

The plots below show the Performance at STC measurement results as a change from Baseline (Stabilized).



Note: Repeatability was calculated as the standard deviation (k=2) of the control module results measured during this project following MQT 19 stabilization. The control modules were taken from the modules provided for this project.

The tables below show the Performance at STC, Visual Inspection, and safety testing results per module. When required, more detail is provided in the section referenced in the “Notes” field.

A module’s ΔPmp (%) was calculated as the change from the *stabilized* value.

Module: 21080-014

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 9.984 | 49.10 | 9.473 | 40.29 | 381.68 | +0.81 | pass | pass | pass |
| Stabilized | 9.958 | 49.12 | 9.422 | 40.18 | 378.60 | - | pass | pass | pass |
| PID_Pos | 9.821 | 48.78 | 9.230 | 39.80 | 367.30 | -2.98 | pass | pass | pass |

Notes:

Module: 21080-020

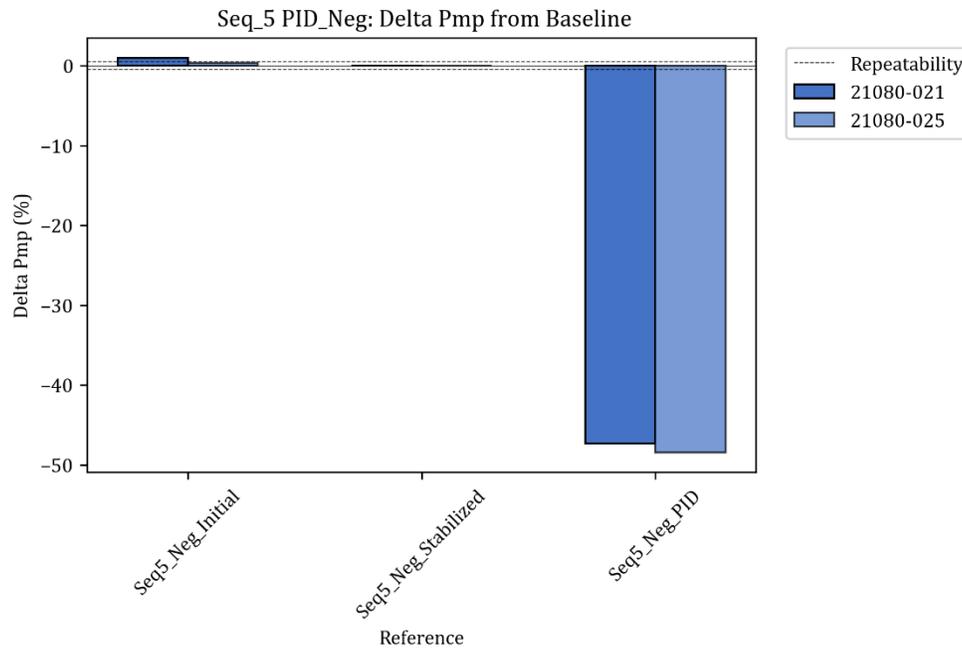
| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | Δ Pmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 9.978 | 49.10 | 9.465 | 40.34 | 381.84 | +0.73 | pass | pass | pass |
| Stabilized | 9.952 | 49.12 | 9.428 | 40.20 | 379.05 | - | pass | pass | pass |
| PID_Pos | 9.798 | 48.85 | 9.217 | 39.84 | 367.21 | -3.12 | pass | pass | pass |

Notes:

Results: Test Leg - Seq_5 Potential-Induced Degradation (PID) Testing (Negative Bias Configuration)

Summary of Results - Performance at STC and Safety Testing

The plots below show the Performance at STC measurement results as a change from Baseline (Stabilized).



Note: Repeatability was calculated as the standard deviation (k=2) of the control module results measured during this project following MQT 19 stabilization. The control modules were taken from the modules provided for this project.

The tables below show the Performance at STC, Visual Inspection, and safety testing results per module. When required, more detail is provided in the section referenced in the “Notes” field.

A module’s ΔPmp (%) was calculated as the change from the *stabilized* value.

Module: 21080-021

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 9.996 | 49.21 | 9.479 | 40.43 | 383.30 | +1.00 | pass | pass | pass |
| Stabilized | 9.972 | 49.05 | 9.428 | 40.25 | 379.51 | - | pass | pass | pass |
| PID_Neg | 9.782 | 41.65 | 7.315 | 27.32 | 199.84 | -47.34 | pass | pass | pass |

Notes:

Module: 21080-025

| Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | Δ Pmp (%) | Visual Inspection | Wet Leakage | Insulation |
|-------------------|---------|---------|---------|---------|---------------|------------------|-------------------|-------------|------------|
| Initial | 10.002 | 49.15 | 9.470 | 40.29 | 381.55 | +0.38 | pass | pass | pass |
| Stabilized | 9.990 | 49.06 | 9.464 | 40.16 | 380.10 | - | pass | pass | pass |
| PID_Neg | 9.788 | 40.58 | 7.395 | 26.48 | 195.84 | -48.48 | pass | pass | pass |

Notes:

Procedures

The procedures for the testing contained in this report are summarized in the following table.

| Test Name | Standard / Procedure | CFV Accreditation |
|--|---------------------------|-------------------|
| Incoming Inspection | CFV | NA |
| Visual Inspection | IEC 61215-2:2016 MQT 01 | ISO 17025 |
| Electroluminescence Imaging | IEC TS 60904-13:2018 | ISO 17025 |
| Stabilization | IEC 61215-2:2016 MQT 19 | ISO 17025 |
| ² Performance at STC | IEC 61215-2:2016 MQT 06.1 | ISO 17025 |
| ³ Performance at Low Irradiance | IEC 61215-2:2016 MQT 07 | ISO 17025 |
| Bifacial IV | IEC TS 62094-1-2:2019 | ISO 17025 |
| Wet Leakage Current | IEC 61215-2:2016 MQT 15 | ISO 17025 |
| Insulation | IEC 61215-2:2016 MQT 03 | ISO 17025 |
| ¹ Static Mechanical Loading | IEC 61215-2:2016 MQT 16 | ISO 17025 |
| Cyclic Mechanical Loading | IEC TS 62782-2:2016 | ISO 17025 |
| UV | IEC 61215-2:2016 MQT 10 | ISO 17025 |
| Thermal Cycling | IEC 61215-2:2016 MQT 11 | ISO 17025 |
| Humidity Freeze | IEC 61215-2:2016 MQT 12 | ISO 17025 |
| Damp Heat | IEC 61215-2:2016 MQT 13 | ISO 17025 |
| Potential Induced Degradation | IEC TS 62804:2015 | ISO 17025 |

Amendments to tests:

¹ IEC 61215-2:2016 MQT 19, requires that modules are operated with MPPT and are measured at multiple intervals during the light exposure to determine stability. For this project, three of the modules tested were measured according to the full MQT 19 protocol (21080-002, 21080-003, and 21080-008). However, the standard allows for the use of an alternative procedure that is validated against the full protocol. In this case, the remaining modules were exposed to the same total dose, but they were only measured before and after the total dose and were operated in open circuit.

² Performance at STC - Test Conditions

| Irradiance [W/m ²] | Temperature [°C] |
|--------------------------------|------------------|
| 1000.0 | 25.0 |

Performance at STC - Estimated Measurement Uncertainty

| Technology | Isc | Voc | Imp | Vmp | Pmp |
|--------------------|---------|----------|---------|---------|---------|
| Si, Bifacial (k=2) | ± 1.6 % | ± 0.75 % | ± 2.1 % | ± 1.3 % | ± 2.2 % |

³ Performance at Low Irradiance - Test Conditions

| Irradiance [W/m ²] | Temperature [°C] |
|--------------------------------|------------------|
| 200.0 | 25.0 |

Performance at Low Irradiance - Estimated Measurement Uncertainty

| Technology | Isc | Voc | Imp | Vmp | Pmp |
|--------------------|---------|----------|---------|---------|---------|
| Si, Bifacial (k=2) | ± 1.6 % | ± 0.75 % | ± 2.1 % | ± 1.3 % | ± 2.2 % |

Equipment Calibration Information

Equipment and Calibration information is available upon request.

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--END OF REPORT--