

21080 Test Report:

IEC TS 63209-1 Sequence 1 Thermal Fatigue Testing on M390-D1FB Modules Produced by Mitrex

Report Number: 21080A-PR-E-001
Report Date: 2022-08-08
Test Period: 2022-02-07 to 2022-07-27
Project ID: 21080 (CFV), 000477 (Customer PO)
Customer: Hadi Khatibzadehazad / Mitrex
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| Report Prepared by: | Report Reviewed by: | Report Approved by: |
|---------------------|---------------------|---------------------|
| | | |

Project Summary

CFV Labs conducted extended reliability testing on two **M390-D1FB** modules produced by **Mitrex** per IEC TS 63209-1 Sequence 1 Thermal Fatigue.

The modules were subjected to performance measurements and safety tests prior to stress testing. The modules were then subjected to three rounds of TC200 for a total thermal cycling dose of 600 cycles. Each test block was followed by post-stress performance and safety measurements.

The average change in STC Pmp [W] from initial to the final post-stress testing was measured to be -5.93 %. The modules passed all safety tests and all initial, interim, and final visual inspections.

This report is sub-report 21080A-PR-E-001 of project 21080. All test legs for this IEC TS 63209-1 project are summarized in report 21080-PR-E-001.

Project Test Flow

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

| Incoming Inspection | Seq_1 Thermal Cycling | Seq_1 Thermal Cycling_Continued |
|--------------------------|---|--------------------------------------|
| All samples | 21080-008, 21080-003 | 21080-008, 21080-003 |
| @Initial | @Seq1_Initial | @Seq1_TC200-2 |
| Incoming Inspection | MQT 06.1 Performance at STC | MQT 11 Thermal Cycling (200 Cycles) |
| MQT 01 Visual Inspection | MQT 07 Performance at Low Irradiance | MQT 01 Visual Inspection |
| EL Imaging 1.0x Isc | @Seq1_Stabilization-1 | MQT 06.1 Performance at STC |
| EL Imaging 0.1x Isc | MQT 19 Stabilization - Outdoor Exposure (40 kWh/m2, MPPT) | MQT 07 Performance at Low Irradiance |
| | MQT 06.1 Performance at STC | EL Imaging 1.0x Isc |
| | @Seq1_Stabilization-2 | MQT 03 Insulation |
| | MQT 19 Stabilization - Outdoor Exposure (40 kWh/m2, MPPT) | MQT 15 Wet Leakage Current |
| | MQT 06.1 Performance at STC | @Seq1_TC200-3 |
| | @Seq1_Stabilization-3 | MQT 11 Thermal Cycling (200 Cycles) |
| | MQT 19 Stabilization - Outdoor Exposure (40 kWh/m2, MPPT) | MQT 01 Visual Inspection |
| | @Seq1_Stabilized | MQT 06.1 Performance at STC |
| | MQT 06.1 Performance at STC | MQT 07 Performance at Low Irradiance |
| | MQT 07 Performance at Low Irradiance | Bifacial Indoor I-V |
| | Bifacial Indoor I-V | EL Imaging 1.0x Isc |
| | EL Imaging 1.0x Isc | EL Imaging 0.1x Isc |
| | EL Imaging 0.1x Isc | MQT 03 Insulation |
| | MQT 03 Insulation | MQT 15 Wet Leakage Current |
| | MQT 15 Wet Leakage Current | |
| | @Seq1_TC200-1 | |
| | MQT 11 Thermal Cycling (200 Cycles) | |
| | MQT 01 Visual Inspection | |
| | MQT 06.1 Performance at STC | |
| | MQT 07 Performance at Low Irradiance | |
| | EL Imaging 1.0x Isc | |
| | MQT 03 Insulation | |
| | MQT 15 Wet Leakage Current | |

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 |
|-----------|---------------|--|-------|
| 21080-002 | MIT21A04827 | Incoming Inspection, Control | - |
| 21080-003 | MIT21A04820 | Incoming Inspection, Seq_1 Thermal Cycling | - |
| 21080-008 | MIT22A00026 | Incoming Inspection, Seq_1 Thermal Cycling | - |

Sample Information

Sample Dimensions

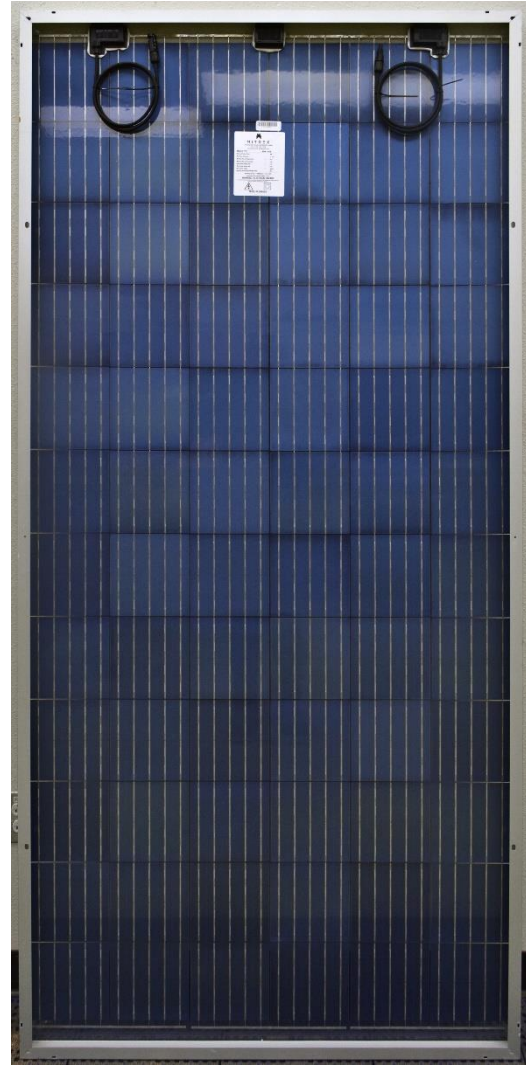
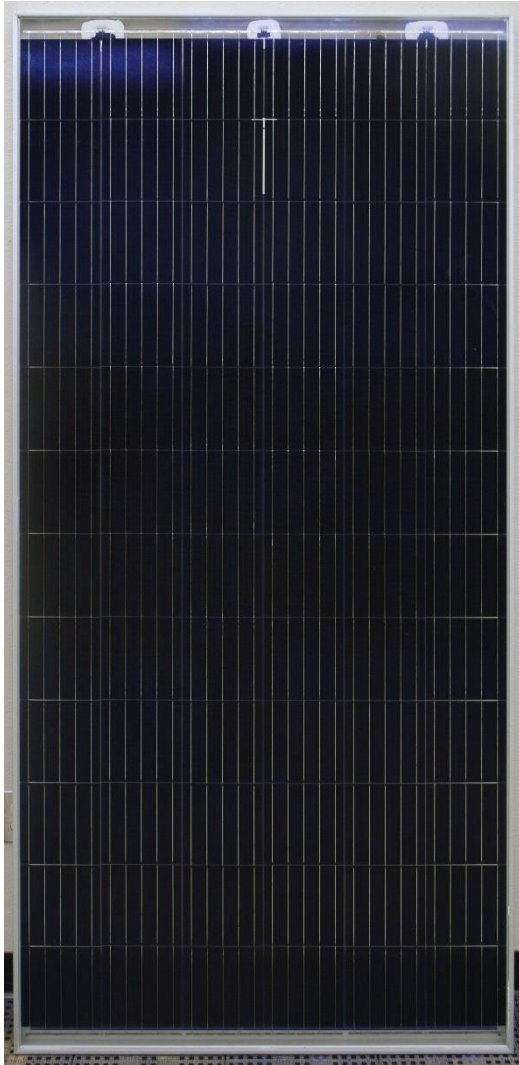
| Module Type | Length [m] | Width [m] | Thickness [mm] |
|-------------|------------|-----------|----------------|
| M390-D1FB | 2.03 | 0.99 | 40 |


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







MITREX
41 Racine Rd, Toronto, ON M9W 2Z4, Canada
Tel: 1-416-497-7120
www.mitrex.com info@mitrex.com

| MODULE TYPE | M390-D1FB |
|---------------------------------------|-----------|
| Maximum Power (Pmax) | 390 |
| Max Power Tolerance | ± 5 % |
| Maximum Power Voltage (Vmp) | 42.0 |
| Maximum Power Current (Imp) | 9.29 |
| Open Circuit Voltage (Voc) | 47.3 |
| Short Circuit Current (Isc) | 9.76 |
| Max. system Voltage | 1000 V |
| Maximum overcurrent protection rating | 20 A |

All ratings at STC: E = 1000W/m² A = 1.5, T = 25°C
Accuracy of other electrical values ± 5 %

WARNING / ELECTRICAL HAZARD
This module produces electricity when exposed to sunlight. Do not disconnect the module under load.
Follow all applicable electrical safety precautions.



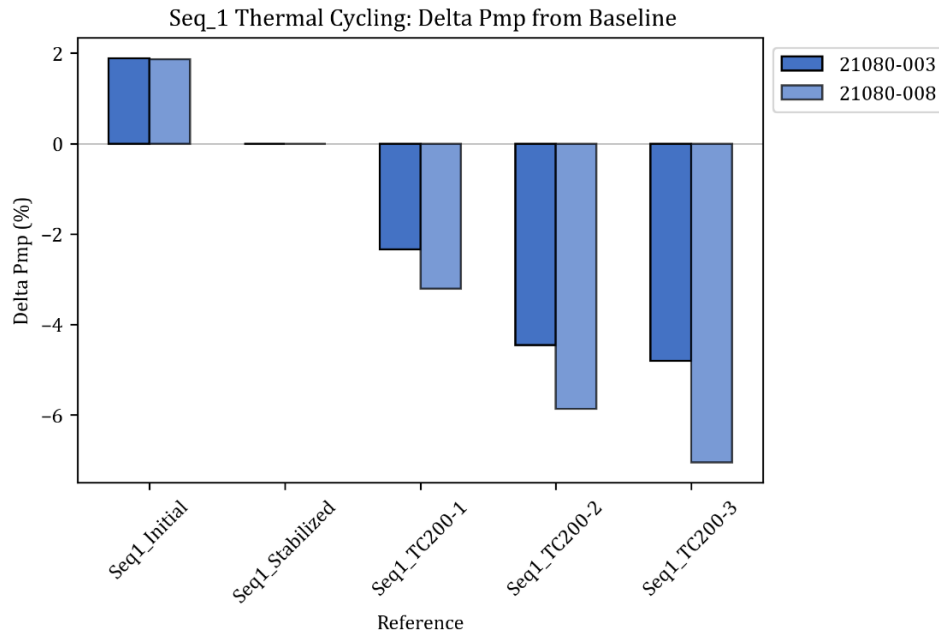
MADE IN CANADA

Results: Test Leg – Seq_1 Thermal Cycling

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

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).



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.

Test Conditions

| Irradiance [W/m2] | Temperature [°C] |
|-------------------|------------------|
| 1000.0 | 25.0 |

Estimated Measurement Uncertainty

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

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:

Performance at STC – Change from Stabilized

| Module ID | Reference | Δ Isc [%] | Δ Voc [%] | Δ Imp [%] | Δ Vmp [%] | Δ Pmp [%] |
|-----------|------------|-----------|-----------|-----------|-----------|-----------|
| 21080-003 | Initial | +0.12 | +0.14 | +1.30 | +0.58 | +1.89 |
| | Stabilized | +0.00 | +0.00 | +0.00 | +0.00 | +0.00 |
| | TC200-1 | -0.16 | -0.31 | -0.20 | -2.15 | -2.34 |
| | TC200-2 | -0.71 | -0.38 | -1.68 | -2.82 | -4.45 |
| | TC200-3 | -0.44 | -0.14 | -1.63 | -3.22 | -4.80 |
| 21080-008 | Initial | -0.01 | +0.20 | +0.64 | +1.21 | +1.86 |
| | Stabilized | +0.00 | +0.00 | +0.00 | +0.00 | +0.00 |
| | TC200-1 | -0.48 | -0.32 | -0.87 | -2.36 | -3.21 |
| | TC200-2 | -1.33 | -0.23 | -2.76 | -3.20 | -5.87 |
| | TC200-3 | -0.61 | -0.14 | -2.64 | -4.54 | -7.05 |

Control Module Measurements

| Module ID | Reference | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-002 | Initial | 9.981 | 49.19 | 9.476 | 40.33 | 382.22 |
| | Stabilized | 9.975 | 49.14 | 9.450 | 40.19 | 379.84 |
| | TC200-1 | 9.964 | 49.12 | 9.455 | 40.27 | 380.69 |
| | TC200-2 | 9.943 | 49.07 | 9.428 | 40.23 | 379.31 |
| | TC200-3 | 9.964 | 49.12 | 9.470 | 40.24 | 381.04 |

Bifacial Performance

Test Conditions

| Irradiance [W/m2] | Temperature [°C] |
|-------------------|------------------|
| 1000.0 | 25.0 |

Estimated Measurement Uncertainty

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

Measurements - Backside

| Module ID | Reference | Isc [A] | Voc [V] | Imp [A] | Vmp [V] | Pmp [W] |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-003 | Stabilized | 6.942 | 48.41 | 6.056 | 42.02 | 254.48 |
| | TC200-3 | 6.737 | 48.32 | 6.026 | 40.94 | 246.70 |
| 21080-008 | Stabilized | 7.015 | 48.48 | 6.236 | 42.06 | 262.27 |
| | TC200-3 | 6.806 | 48.29 | 6.069 | 40.44 | 245.41 |

Bifaciality Calculations

| Module ID | Reference | φ_Isc [%] | φ_Voc [%] | φ_Imp [%] | φ_Vmp [%] | φ_Pmp [%] |
|-----------|------------|-----------|-----------|-----------|-----------|-----------|
| 21080-003 | Stabilized | 69.75 | 98.59 | 64.89 | 104.61 | 67.88 |
| | TC200-3 | 67.99 | 98.54 | 65.63 | 105.32 | 69.12 |
| 21080-008 | Stabilized | 70.27 | 98.77 | 66.01 | 104.63 | 69.07 |
| | TC200-3 | 68.59 | 98.51 | 65.98 | 105.39 | 69.53 |

Performance at Low Irradiance

Test Conditions

| Irradiance [W/m2] | Temperature [°C] |
|-------------------|------------------|
| 200.0 | 25.0 |

Estimated Measurement Uncertainty

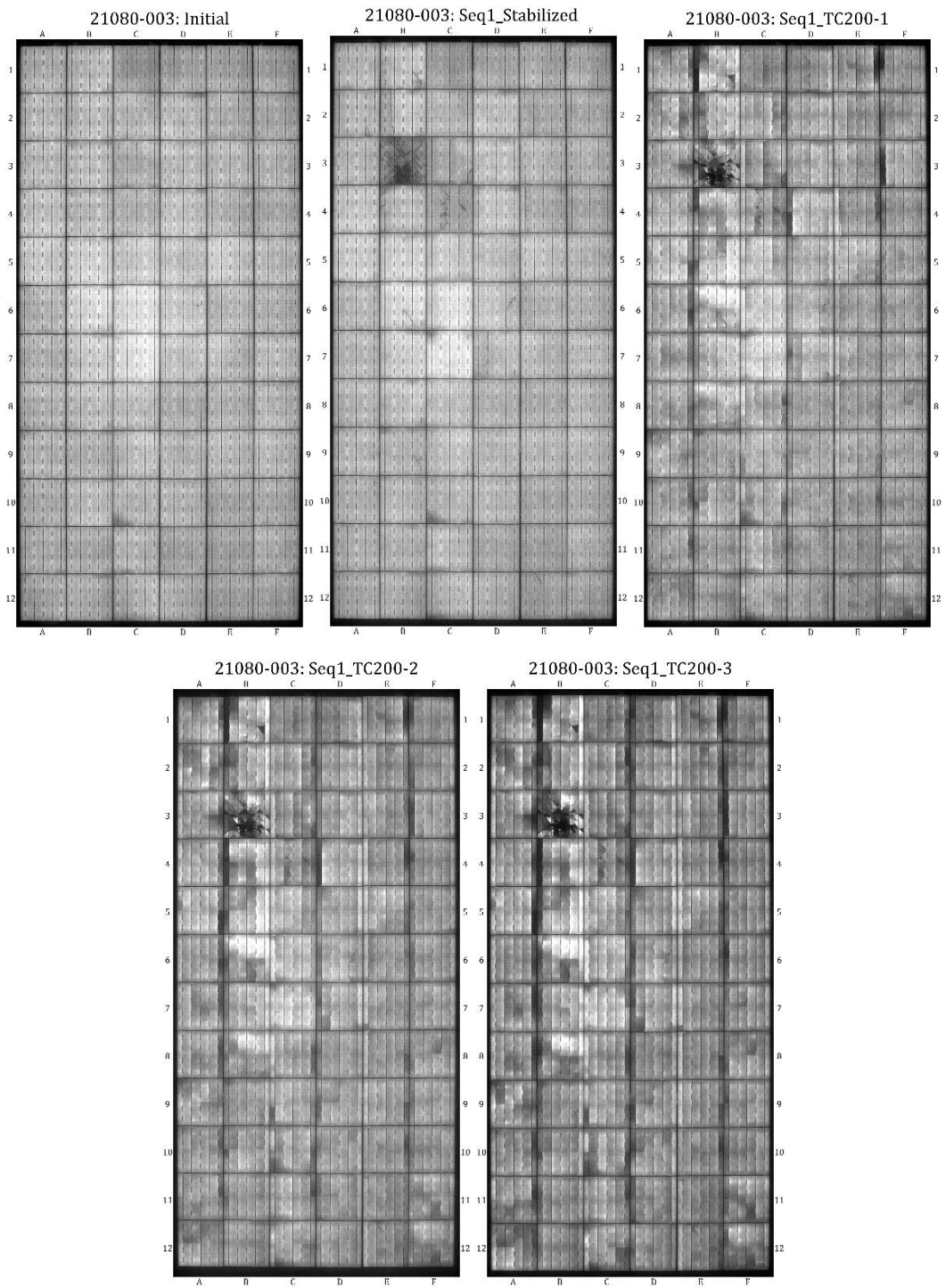
| Technology | Isc | Voc | Imp | Vmp | Pmp |
|--------------------|---------|----------|---------|---------|---------|
| Si, Bifacial (k=2) | ± 1.6 % | ± 0.75 % | ± 2.1 % | ± 1.3 % | ± 2.2 % |

Measurements

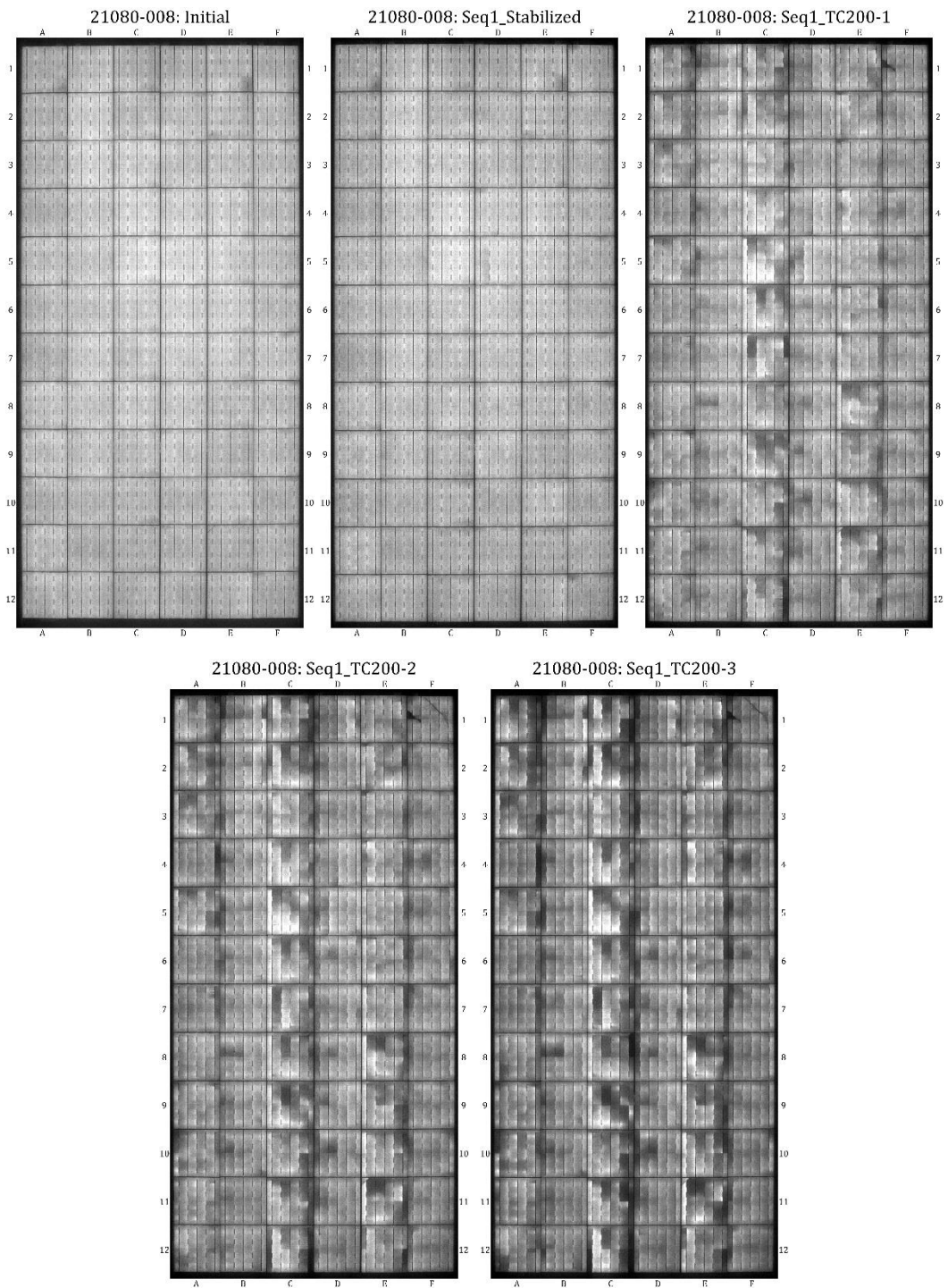
| Module ID | Reference | Isc [A] | Voc [V] | Imp [A] | Vmp [V] | Pmp [W] |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-003 | Initial | 1.990 | 46.14 | 1.885 | 39.52 | 74.51 |
| | Stabilized | 1.999 | 45.86 | 1.825 | 38.69 | 70.61 |
| | TC200-1 | 1.994 | 45.82 | 1.857 | 38.76 | 71.96 |
| | TC200-2 | 1.981 | 45.78 | 1.843 | 38.70 | 71.31 |
| | TC200-3 | 1.996 | 45.76 | 1.861 | 38.60 | 71.86 |
| 21080-008 | Initial | 2.002 | 46.05 | 1.892 | 39.66 | 75.04 |
| | Stabilized | 2.003 | 45.98 | 1.886 | 39.26 | 74.05 |
| | TC200-1 | 2.000 | 45.77 | 1.873 | 38.86 | 72.80 |
| | TC200-2 | 1.988 | 45.66 | 1.856 | 38.68 | 71.80 |
| | TC200-3 | 1.999 | 45.70 | 1.873 | 38.52 | 72.14 |

Electroluminescence Imaging

Module 21080-003 (Images taken at 0.1 x Isc are provided separately in digital format)



Module 21080-008 (Images taken at 0.1 x Isc are provided separately in digital format)



Stabilization

Pass/Fail also determined by follow-up MQT 01 Visual Inspection and MQT 15 Wet Leakage Current.

| Module | Reference | Total Dose [kWh/m ²] | Pmp - Delta from Initial [%] |
|-----------|--------------|----------------------------------|------------------------------|
| 21080-003 | Stabilized | 141.27 | -1.85 |
| 21080-008 | Stabilized | 99.99 | -1.82 |
| 21080-002 | Z_Stabilized | 141.27 | -0.62 |

Thermal Cycling

Pass/Fail also determined by follow-up MQT 01 Visual Inspection and MQT 15 Wet Leakage Current.

| Module | Reference | Cycle Count | Total Cycle Count | Temp - High [°C] | Temp - Low [°C] | Pass/Fail |
|-----------|-----------|-------------|-------------------|------------------|-----------------|-----------|
| 21080-003 | TC200-1 | 200 | 200 | 85 | -40 | Pass |
| 21080-003 | TC200-2 | 200 | 400 | 85 | -40 | Pass |
| 21080-003 | TC200-3 | 200 | 600 | 85 | -40 | Pass |
| 21080-008 | TC200-1 | 200 | 200 | 85 | -40 | Pass |
| 21080-008 | TC200-2 | 200 | 400 | 85 | -40 | Pass |
| 21080-008 | TC200-3 | 200 | 600 | 85 | -40 | Pass |

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 |
| Preconditioning | IEC 61215-2:2016 MQT 19 | ISO 17025 |
| Performance at STC | IEC 61215-2:2016 MQT 06.1 | ISO 17025 |
| Performance at Low Irradiance | IEC 61215-2:2016 MQT 07 | ISO 17025 |
| Wet Leakage Current | IEC 61215-2:2016 MQT 15 | ISO 17025 |
| Insulation | IEC 61215-2:2016 MQT 03 | ISO 17025 |
| Thermal Cycling | IEC 61215-2:2016 MQT 11 | ISO 17025 |

Equipment Calibration Information

Equipment and Calibration information is available upon request.

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