

## 21080 Test Report:

### IEC TS 63209-1 Sequence 5 Potential Induced Degradation Testing on M390-D1FB Modules Produced by Mitrex

**Report Number:** 21080E-PR-E-001  
**Report Date:** 2022-06-28  
**Test Period:** 2022-02-07 to 2022-06-24  
**Project ID:** 21060 (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 5.

The modules were subjected to performance measurements and safety tests prior to stress testing. The modules were then subjected to 192 hours of PID stress (two modules per polarity), which was followed by post-stress performance and safety tests.

The average change in STC Pmp [W] from initial to the final post-stress testing was measured to be -3.05 % and -47.91 % for the positive and negative polarity test respectively. The modules passed all safety tests and all visual inspections.

This report is sub-report 21080E-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_5 PID_Pos   | Seq_5 PID_Neg   |
|--------------------------|---|---|
| All samples              | 21080-014, 21080-020  | 21080-021, 21080-025  |
| @Initial                 | @Seq5_Pos_Initial   | @Seq5_Neg_Initial   |
| Incoming Inspection      | MQT 06.1 Performance at STC                                   | MQT 06.1 Performance at STC                                   |
| MQT 01 Visual Inspection | MQT 07 Performance at Low Irradiance                          | MQT 07 Performance at Low Irradiance                          |
| EL Imaging 1.0x Isc      | @Seq5_Pos_Stabilization                                       | @Seq5_Neg_Stabilization                                       |
| EL Imaging 0.1x Isc      | MQT 19 Stabilization - Outdoor Exposure<br>(120 kWh/m2, MPPT) | MQT 19 Stabilization - Outdoor Exposure<br>(120 kWh/m2, MPPT) |
|                          | @Seq5_Pos_Stabilized  | @Seq5_Neg_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                                    |
|                          | @Seq5_Pos_PID   | @Seq5_Neg_PID   |
|                          | Positive PID<br>(192 Hours)                                   | Negative PID<br>(192 Hours)                                   |
|                          | MQT 01 Visual Inspection                                      | MQT 01 Visual Inspection                                      |
|                          | 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                                    |

## 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, Z_Control     | -     |
| 21080-014 | MIT22A00009   | Incoming Inspection, Seq_5 PID Pos | -     |
| 21080-020 | MIT21A04872   | Incoming Inspection, Seq_5 PID Pos | -     |
| 21080-021 | MIT21A04871   | Incoming Inspection, Seq_5 PID Neg | -     |
| 21080-025 | MIT21A04822   | Incoming Inspection, Seq_5 PID Neg | -     |

## Sample Information

### Sample Dimensions

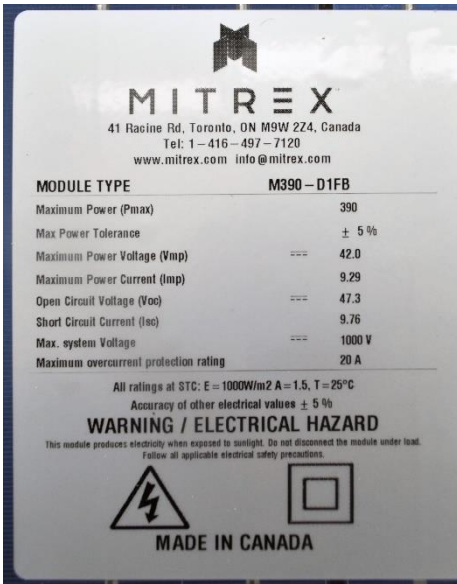
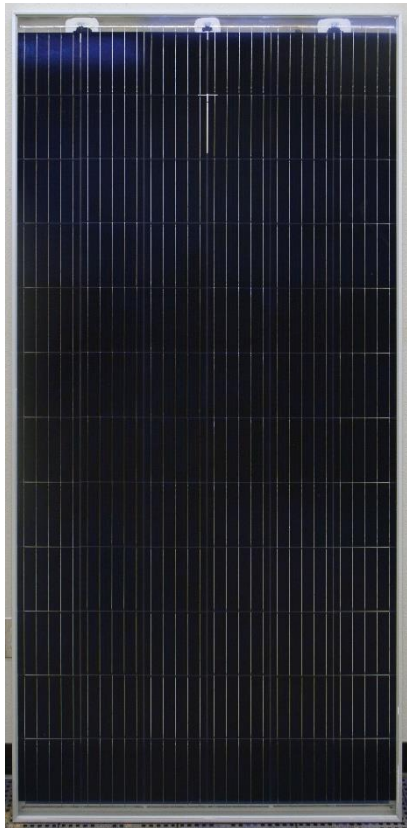
| Module Manufacturer | Module Type | Length [m] | Width [m] | Thickness [mm] |
|---------------------|-------------|------------|-----------|----------------|
| Mitrex              | M390-D1FB   | 2.03       | 0.99      | 40             |

### 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    | 42.07   | 390     | 1000             | 20              |

Sample Type Images

Module (M390-D1FB)



Results: Test Leg – Incoming Inspection

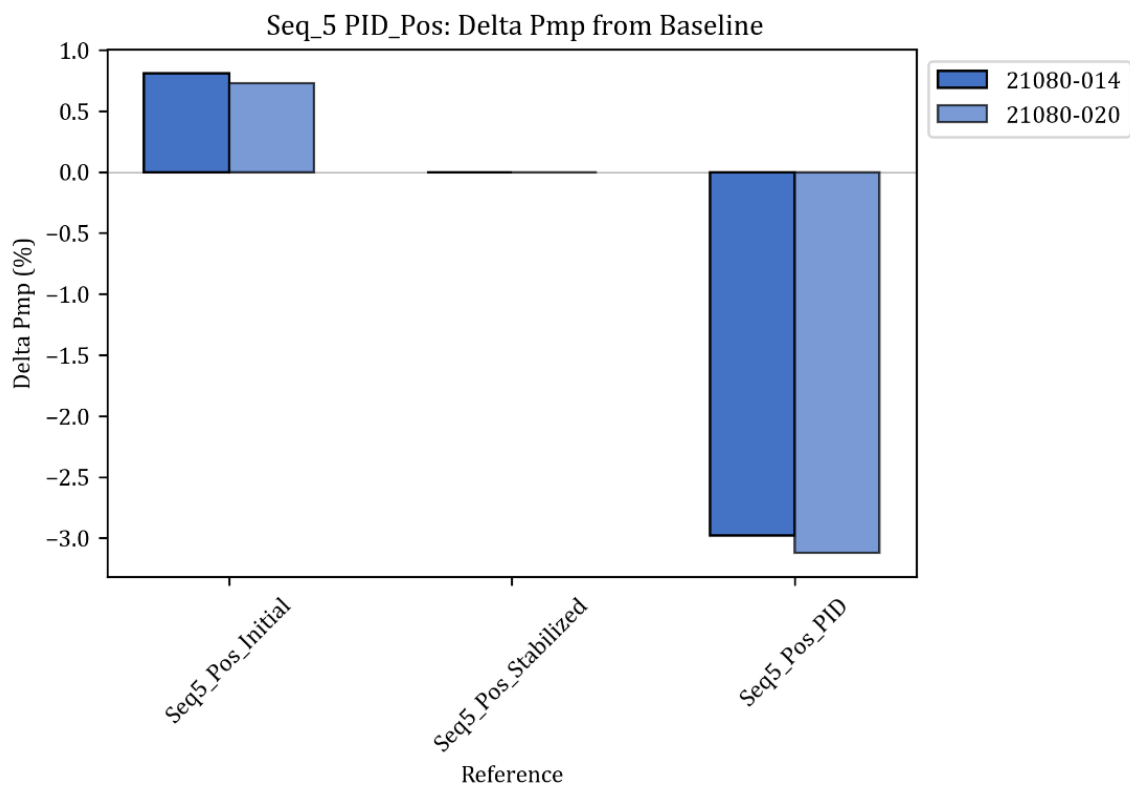
An incoming inspection report is provided separately to the customer. No issues were observed during the incoming inspection.

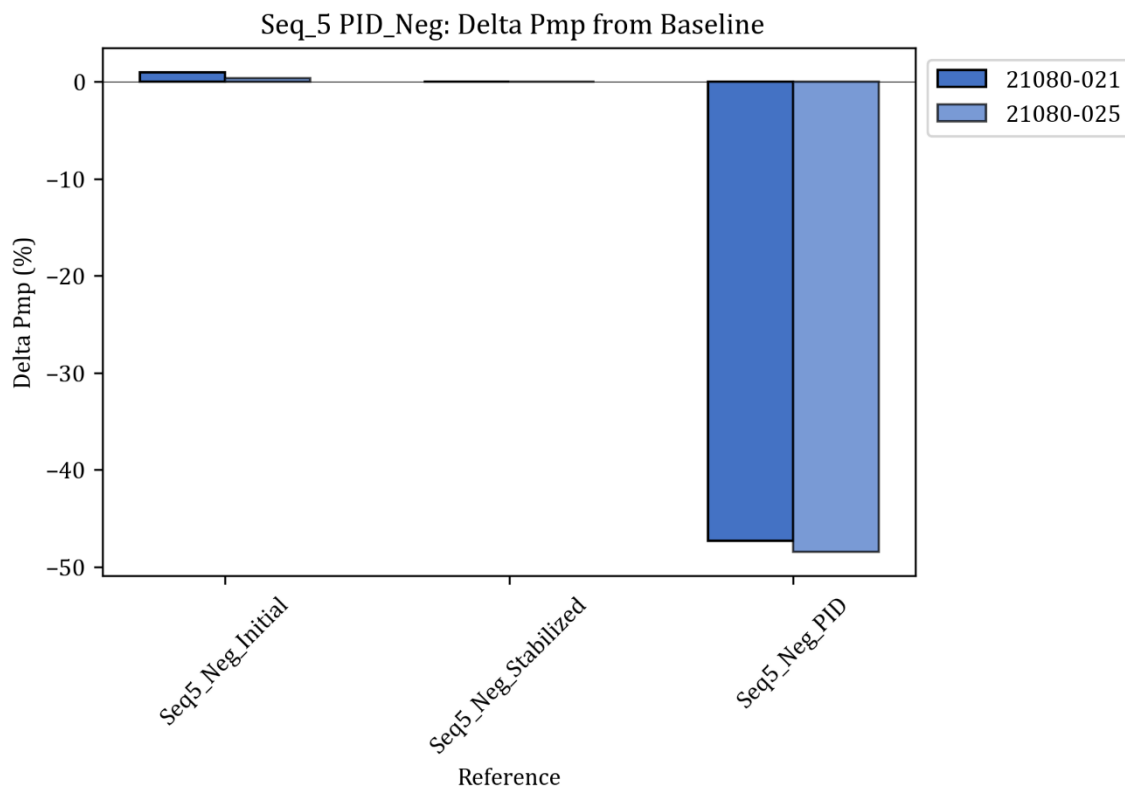
Results: Test Leg – Seq\_5 PID\_Pos/Neg

Results for both the positive (pos) and negative (neg) polarity tests are presented in this section.

Summary of Results – Performance at STC and Safety Testing

The plots below show the Performance at STC measurement values as a percentage change from the Stabilized values.





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: 21080-014

| 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       |

## Module: 21080-020

| Reference  | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | 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       |

## 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       |

## Module: 21080-025

| Reference  | Isc (A) | Voc (V) | Imp (A) | Vmp (V) | Pmp (W) | ΔPmp (%) | 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       |

## Performance at STC – Change from Stabilized

| Module ID | Reference  | Δ Isc [%] | Δ Voc [%] | Δ Imp [%] | Δ Vmp [%] | Δ Pmp [%] |
|-----------|------------|-----------|-----------|-----------|-----------|-----------|
| 21080-014 | Initial    | +0.25     | -0.03     | +0.54     | +0.27     | +0.81     |
|           | Stabilized | +0.00     | +0.00     | +0.00     | +0.00     | +0.00     |
|           | PID_Pos    | -1.38     | -0.68     | -2.04     | -0.96     | -2.98     |
| 21080-020 | Initial    | +0.27     | -0.04     | +0.39     | +0.34     | +0.73     |
|           | Stabilized | +0.00     | +0.00     | +0.00     | +0.00     | +0.00     |
|           | PID_Pos    | -1.55     | -0.55     | -2.24     | -0.91     | -3.12     |
| 21080-021 | Initial    | +0.24     | +0.33     | +0.54     | +0.45     | +1.00     |
|           | Stabilized | +0.00     | +0.00     | +0.00     | +0.00     | +0.00     |
|           | PID_Neg    | -1.90     | -15.09    | -22.42    | -32.13    | -47.34    |
| 21080-025 | Initial    | +0.13     | +0.19     | +0.06     | +0.32     | +0.38     |
|           | Stabilized | +0.00     | +0.00     | +0.00     | +0.00     | +0.00     |
|           | PID_Neg    | -2.02     | -17.29    | -21.87    | -34.06    | -48.48    |

## Control Module Measurements (21060-024)

| 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  |
|           | PID        | 9.939   | 49.10   | 9.418   | 40.25   | 379.12  |

## Bifacial Performance

Note: Front-side measurements are presented in Summary of Results – Performance and Safety Testing

### Test Conditions

| Irradiance [W/m <sup>2</sup> ] | 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] |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-014 | Stabilized | 6.783   | 48.44   | 6.095   | 41.99   | 255.93  |
|           | PID_Pos    | 6.771   | 48.32   | 6.049   | 41.69   | 252.21  |
| 21080-020 | Stabilized | 6.823   | 48.45   | 5.962   | 42.45   | 253.13  |
|           | PID_Pos    | 6.772   | 48.24   | 5.921   | 42.03   | 248.86  |
| 21080-021 | Stabilized | 6.976   | 48.43   | 5.856   | 42.72   | 250.20  |
|           | PID_Neg    | 6.953   | 38.72   | 5.137   | 25.21   | 129.51  |
| 21080-025 | Stabilized | 7.010   | 48.46   | 5.476   | 43.37   | 237.49  |
|           | PID_Neg    | 7.024   | 37.90   | 5.132   | 25.08   | 128.70  |

*Measurements - Bifaciality*

| Module ID | Reference  | $\phi_{Isc}$ [%] | $\phi_{Voc}$ [%] | $\phi_{Imp}$ [%] | $\phi_{Vmp}$ [%] | $\phi_{Pmp}$ [%] |
|-----------|------------|------------------|------------------|------------------|------------------|------------------|
| 21080-014 | Stabilized | 68.11            | 98.63            | 64.69            | 104.49           | 67.60            |
|           | PID_Pos    | 68.94            | 99.06            | 65.54            | 104.77           | 68.67            |
| 21080-020 | Stabilized | 68.56            | 98.64            | 63.24            | 105.60           | 66.78            |
|           | PID_Pos    | 69.11            | 98.76            | 64.23            | 105.50           | 67.77            |
| 21080-021 | Stabilized | 69.95            | 98.74            | 62.12            | 106.14           | 65.93            |
|           | PID_Neg    | 71.08            | 92.99            | 70.23            | 92.28            | 64.81            |
| 21080-025 | Stabilized | 70.18            | 98.79            | 57.86            | 107.98           | 62.48            |
|           | PID_Neg    | 71.76            | 93.39            | 69.40            | 94.70            | 65.72            |

**Performance at Low Irradiance***Test Conditions*

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

*Estimated Measurement Uncertainty*

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

*Measurements*

| Module ID | Reference  | Isc [A] | Voc [V] | Imp [A] | Vmp [V] | Pmp [W] |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-014 | Initial    | 1.995   | 46.03   | 1.887   | 39.40   | 74.36   |
|           | Stabilized | 1.999   | 45.92   | 1.872   | 39.12   | 73.21   |
|           | PID_Pos    | 1.973   | 45.64   | 1.840   | 38.75   | 71.31   |
| 21080-020 | Initial    | 1.988   | 46.01   | 1.886   | 39.41   | 74.32   |
|           | Stabilized | 1.998   | 45.91   | 1.881   | 39.20   | 73.73   |
|           | PID_Pos    | 1.966   | 45.60   | 1.841   | 38.66   | 71.16   |
| 21080-021 | Initial    | 2.000   | 46.09   | 1.890   | 39.47   | 74.61   |
|           | Stabilized | 2.002   | 45.94   | 1.862   | 39.19   | 72.98   |
|           | PID_Neg    | 1.963   | 28.15   | 1.436   | 18.17   | 26.10   |
| 21080-025 | Initial    | 1.999   | 46.13   | 1.888   | 39.45   | 74.47   |
|           | Stabilized | 1.999   | 45.97   | 1.892   | 39.32   | 74.38   |
|           | PID_Neg    | 1.963   | 27.81   | 1.442   | 18.22   | 26.27   |

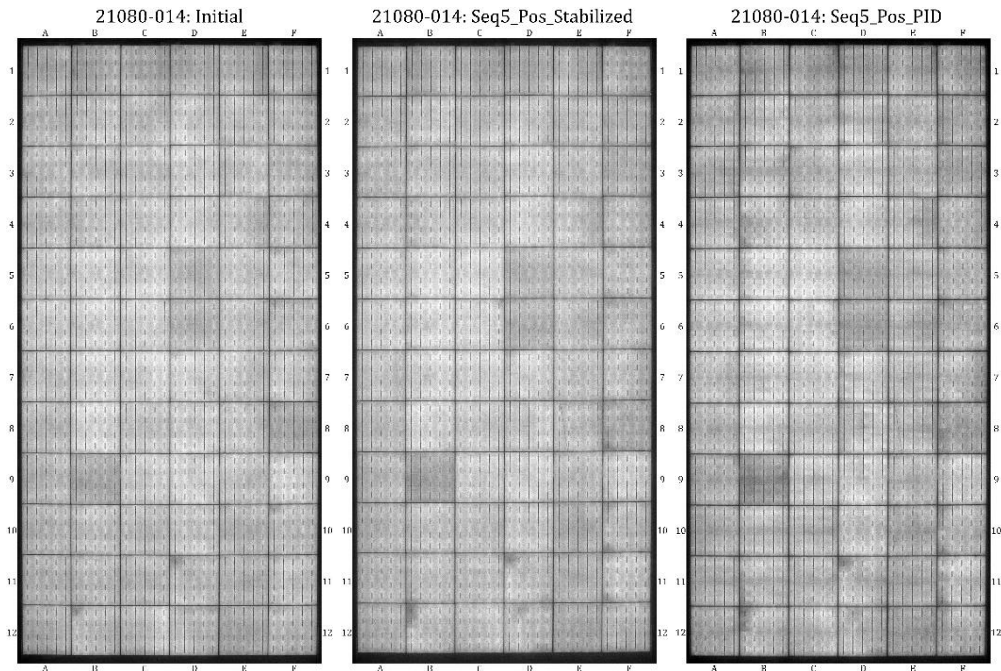
**Stabilization**

Modules were stabilized for a total dose of 145.78 kWh/m<sup>2</sup>.

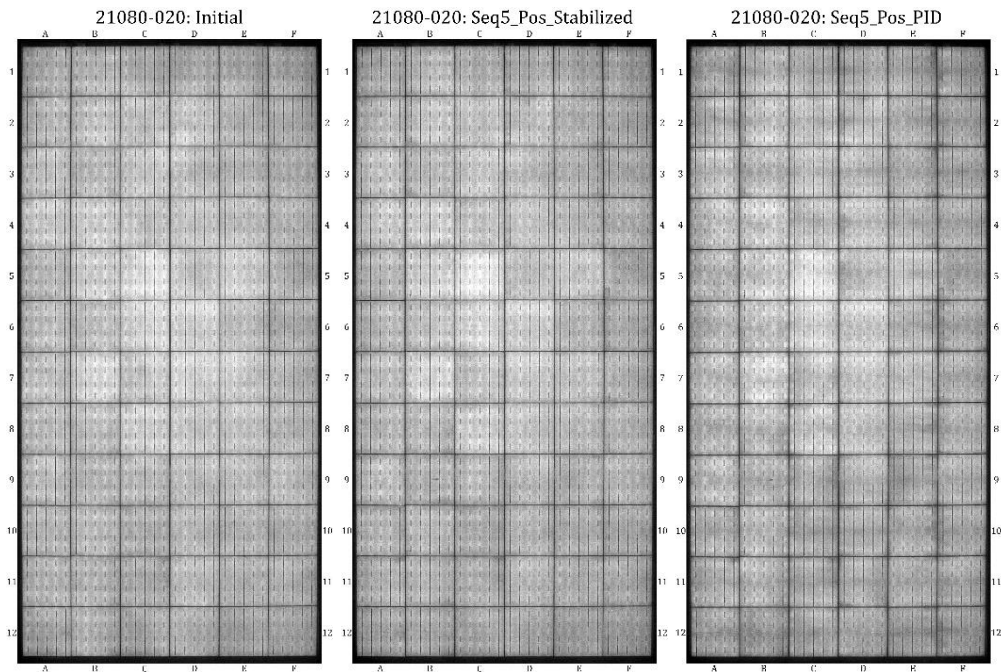


Electroluminescence Imaging

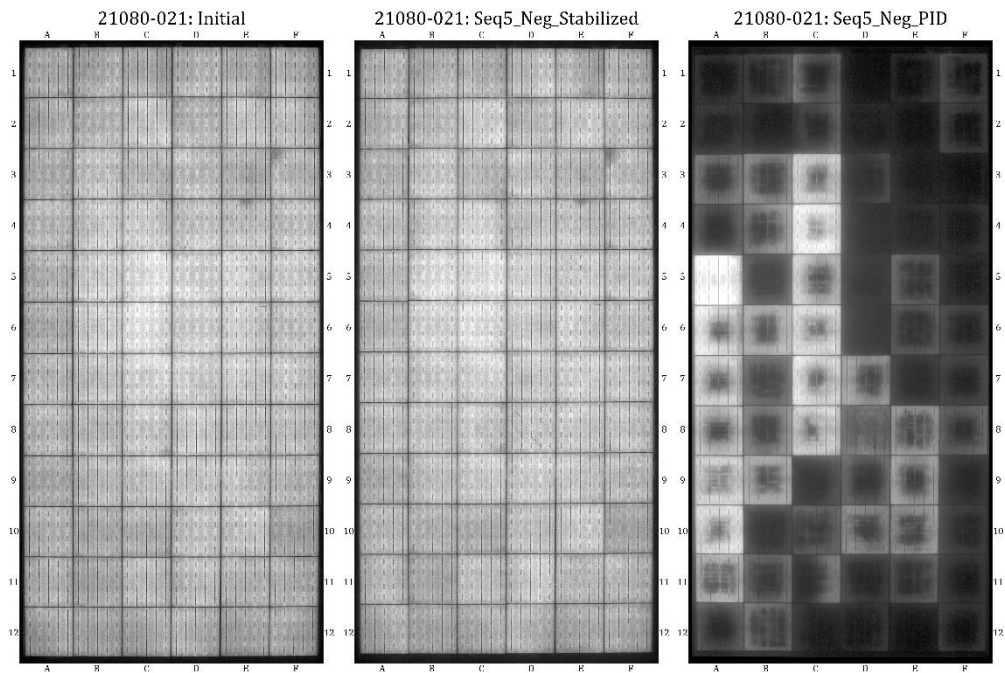
Module 21080-014 (Images taken at 0.1 x Isc are provided separately in digital format)



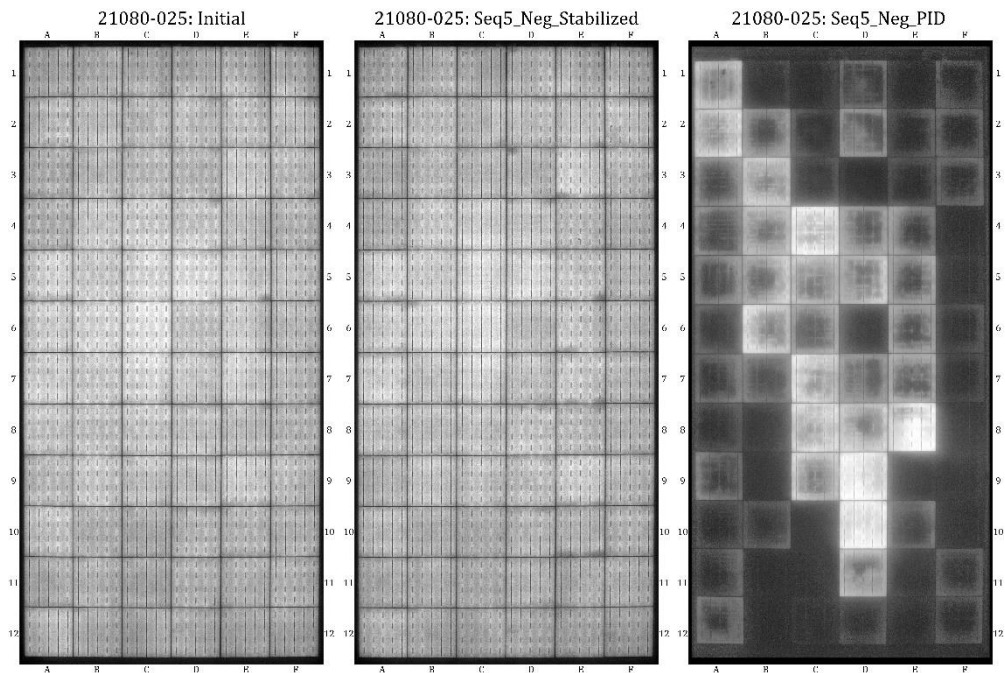
Module 21080-020 (Images taken at 0.1 x Isc are provided separately in digital format)



Module 21080-021 (Images taken at 0.1 x Isc are provided separately in digital format)



Module 21080-025 (Images taken at 0.1 x Isc are provided separately in digital format)



**Potential Induced Degradation**

| Module    | Reference    | Hour Count | Applied Bias [V] | Temp [°C] | Humidity [% RH] |
|-----------|--------------|------------|------------------|-----------|-----------------|
| 21080-014 | Seq5_PID_Pos | 192        | +1000            | 85        | 85              |
| 21080-020 | Seq5_PID_Pos | 192        | +1000            | 85        | 85              |
| 21080-021 | Seq5_PID_Neg | 192        | -1000            | 85        | 85              |
| 21080-025 | Seq5_PID_Neg | 192        | -1000            | 85        | 85              |

**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         |
| Performance at STC            | IEC 61215-2:2016 MQT 06.1 | ISO 17025         |
| Performance at Low Irradiance | IEC 61215-2:2016 MQT 07   | ISO 17025         |
| Bifacial Performance          | IEC TS 60904-1-2:2019     | ISO 17025         |
| Wet Leakage Current           | IEC 61215-2:2016 MQT 15   | ISO 17025         |
| Insulation                    | IEC 61215-2:2016 MQT 03   | ISO 17025         |
| Potential Induced Degradation | IEC TS 62804:2015         | ISO 17025         |

*Amendments to tests:*

\*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.

**Equipment Calibration Information**

Equipment and Calibration information is available upon request.



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