

## 21080 Test Report: IEC TS 63209-1 Sequence 2 Mechanical Stress Testing on M390-D1FB Modules Produced by Mitrex

**Report Number:** 21080B-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  
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 two **M390-D1FB** modules produced by **Mitrex** per IEC TS 63209-1 Sequence 2 Mechanical Stress.

The modules were subjected to performance measurements and safety tests prior to stress testing. One module was subjected to the whole sequence of Static Mechanical Loading (SMLT), Dynamic Mechanical Loading (DMLT), 50 thermal cycles (TC50), and 10 humidity/freezing cycles (HF10). A second module, used as a reference for mechanical stress, was subjected to DMLT, TC50, and HF10 only. Each test block on both modules was followed by post-stress performance and safety measurements.

The change in STC Pmp [W] from initial to the final post-stress testing for the standard and reference modules respectively was measured to be *-11.89 % and -5.56 %*. The modules passed all safety tests and all initial, interim, and final visual inspections.

This report is sub-report 21080B-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_2a SMLT   | Seq_2b SMLT-Reference   |
|--------------------------|---|---|
| All samples              | 21080 005   | 21080 009   |
| @Initial                 | @Seq2a_Initial  | @Seq2b_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      | @Seq2a_Stabilization  | @Seq2b_Stabilization  |
| EL Imaging 0.1x Isc      | MQT 19 Stabilization - Outdoor Exposure (120 kWh/m <sup>2</sup> , MPPT) | MQT 19 Stabilization - Outdoor Exposure (120 kWh/m <sup>2</sup> , MPPT) |
|                          | @Seq2a_Stabilized   | @Seq2b_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  |
|                          | @Seq2a_SMLT   | @Seq2b_DMLT   |
|                          | MQT 16 Static Mechanical Load (+/-2400 Pa)                              | Cyclic Mechanical Loading (+/-1000 Pa, 6 cycles/min)                    |
|                          | 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                                    |
|                          | EL Imaging 1.0x Isc   | EL Imaging 1.0x Isc   |
|                          | MQT 03 Insulation   | MQT 03 Insulation   |
|                          | MQT 15 Wet Leakage Current  | MQT 15 Wet Leakage Current  |
|                          | @Seq2a_DMLT   | @Seq2b_TC50-1   |
|                          | Cyclic Mechanical Loading (+/-1000 Pa, 6 cycles/min)                    | MQT 11 Thermal Cycling (50 Cycles)                                      |
|                          | 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                                    |
|                          | EL Imaging 1.0x Isc   | EL Imaging 1.0x Isc   |
|                          | MQT 03 Insulation   | MQT 03 Insulation   |
|                          | MQT 15 Wet Leakage Current  | MQT 15 Wet Leakage Current  |
|                          | @Seq2a_TC50-1   | @Seq2b_HF10-1   |
|                          | MQT 11 Thermal Cycling (50 Cycles)                                      | MQT 12 Humidity Freeze  |
|                          | MQT 01 Visual Inspection (Within 2-4 hours following HF)                | MQT 01 Visual Inspection (Within 2-4 hours following HF)                |
|                          | MQT 06.1 Performance at STC   | MQT 15 Wet Leakage Current (Within 2-4 hours following HF)              |
|                          | MQT 07 Performance at Low Irradiance                                    | MQT 06.1 Performance at STC   |
|                          | EL Imaging 1.0x Isc   | MQT 07 Performance at Low Irradiance                                    |
|                          | MQT 03 Insulation   | Bifacial Indoor I-V   |
|                          | MQT 15 Wet Leakage Current  | EL Imaging 1.0x Isc   |
|                          | @Seq2a_HF10-1   | EL Imaging 0.1x Isc   |
|                          | MQT 12 Humidity Freeze  | MQT 03 Insulation   |
|                          | MQT 01 Visual Inspection (Within 2-4 hours following HF)                |   |
|                          | MQT 15 Wet Leakage Current (Within 2-4 hours following HF)              |   |
|                          | MQT 06.1 Performance at STC   |   |
|                          | MQT 07 Performance at Low Irradiance                                    |   |
|                          | Bifacial Indoor I-V   |   |
|                          | EL Imaging 1.0x Isc   |   |
|                          | EL Imaging 0.1x Isc   |   |
|                          | MQT 03 Insulation   |   |

## 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               | -     |
| 21080-005 | MIT22A00020   | Incoming Inspection, Seq_2a SMLT           | -     |
| 21080-009 | MIT21A04856   | Incoming Inspection, Seq_2b SMLT-Reference | -     |

## Sample Information

### Sample Dimensions

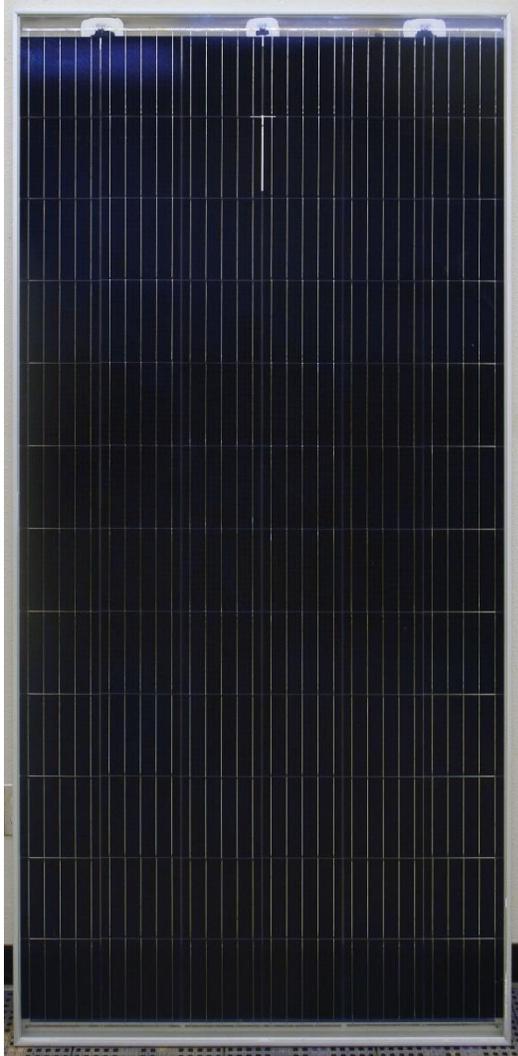
| Module Type | Length [m] | Width [m] | Thickness [mm] |
|-------------|------------|-----------|----------------|
| M390-D1FB   | 2.03       | 0.99      | 40             |

### 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



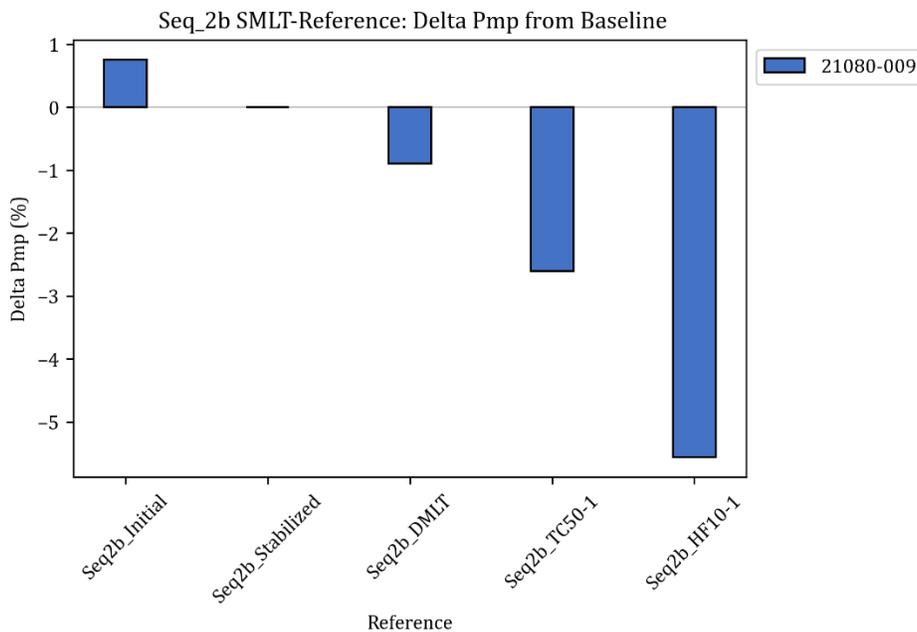
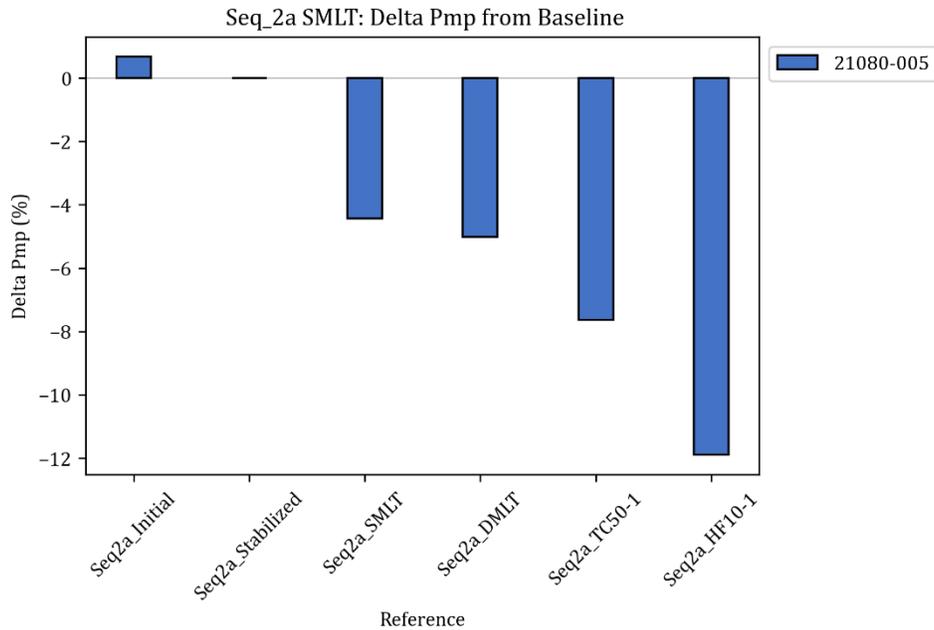


## Results: Test Leg – Seq\_2a SMLT and Seq2b SMLT-Reference

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/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 % |

*Module: 21080-005*

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

Notes:

*Module: 21080-009*

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

Notes:

*Performance at STC – Change from Stabilized*

| Module ID        | Reference  | Δ Isc [%] | Δ Voc [%] | Δ Imp [%] | Δ Vmp [%] | Δ Pmp [%] |
|------------------|------------|-----------|-----------|-----------|-----------|-----------|
| <b>21080-005</b> | Initial    | +0.12     | +0.02     | +0.24     | +0.42     | +0.67     |
|                  | Stabilized | +0.00     | +0.00     | +0.00     | +0.00     | +0.00     |
|                  | SMLT       | -0.22     | -0.48     | -3.68     | -0.79     | -4.43     |
|                  | DMLT       | -0.18     | -0.46     | -4.27     | -0.78     | -5.01     |
|                  | TC50       | 0.06      | -0.65     | -5.42     | -2.35     | -7.64     |
|                  | HF10       | -1.46     | -0.68     | -8.71     | -3.48     | -11.89    |
| <b>21080-009</b> | Initial    | +0.27     | +0.05     | +0.31     | +0.45     | +0.75     |
|                  | Stabilized | +0.00     | +0.00     | +0.00     | +0.00     | +0.00     |
|                  | DMLT       | -0.19     | -0.17     | -0.66     | -0.23     | -0.89     |
|                  | TC50       | 0.08      | -0.37     | -1.26     | -1.36     | -2.60     |
|                  | HF10       | -1.34     | -0.32     | -3.85     | -1.78     | -5.56     |

## 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  |
|           | SMLT       | 9.943   | 49.07   | 9.428   | 40.23   | 379.31  |
|           | DMLT       | 9.946   | 49.10   | 9.436   | 40.20   | 379.32  |
|           | TC50       | 9.971   | 49.17   | 9.468   | 40.25   | 381.12  |
|           | HF10       | 9.964   | 49.12   | 9.470   | 40.24   | 381.04  |

## Bifacial Performance

### 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] |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-005 | Stabilized | 7.011   | 48.45   | 6.261   | 41.81   | 261.80  |
|           | HF10       | 6.739   | 48.26   | 5.945   | 39.52   | 234.93  |
| 21080-009 | Stabilized | 7.013   | 48.58   | 6.330   | 41.90   | 265.18  |
|           | HF10       | 6.744   | 48.25   | 5.921   | 41.15   | 243.67  |

### Bifaciality Calculations

| Module ID | Reference  | $\phi$ _Isc [%] | $\phi$ _Voc [%] | $\phi$ _Imp [%] | $\phi$ _Vmp [%] | $\phi$ _Pmp [%] |
|-----------|------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 21080-005 | Stabilized | 70.40           | 98.59           | 66.22           | 104.20          | 69.01           |
|           | HF10       | 68.67           | 98.88           | 68.87           | 102.05          | 70.28           |
| 21080-009 | Stabilized | 70.30           | 98.91           | 67.06           | 104.45          | 70.04           |
|           | HF10       | 68.53           | 98.53           | 65.24           | 104.46          | 68.15           |

## Performance at Low Irradiance

### Test Conditions

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

### Estimated Measurement Uncertainty

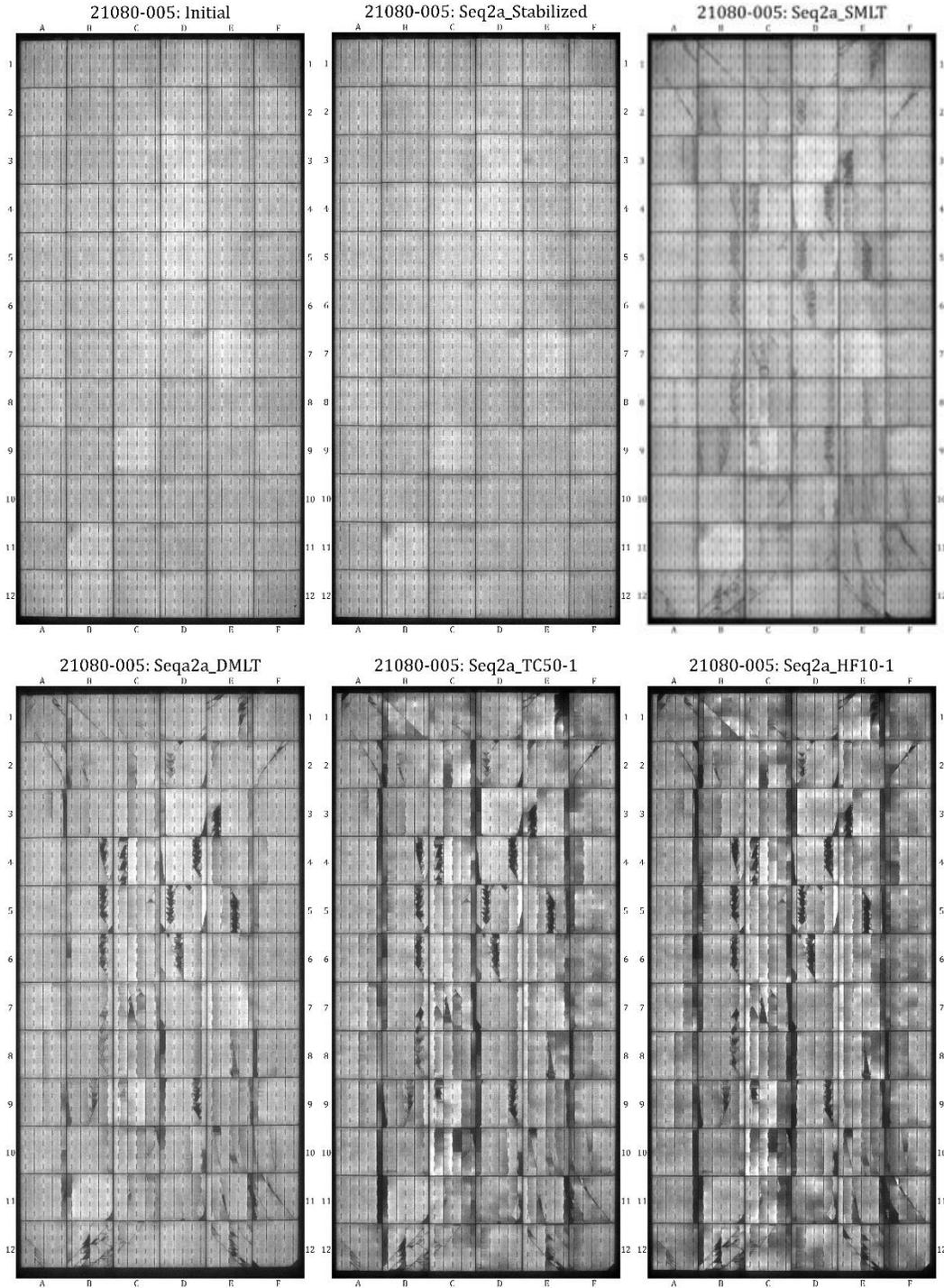
| Technology         | Isc     | Voc      | Imp     | Vmp     | Pmp     |
|--------------------|---------|----------|---------|---------|---------|
| Si, Bifacial (k=2) | ± 1.6 % | ± 0.75 % | ± 2.1 % | ± 1.3 % | ± 2.2 % |

### Measurements

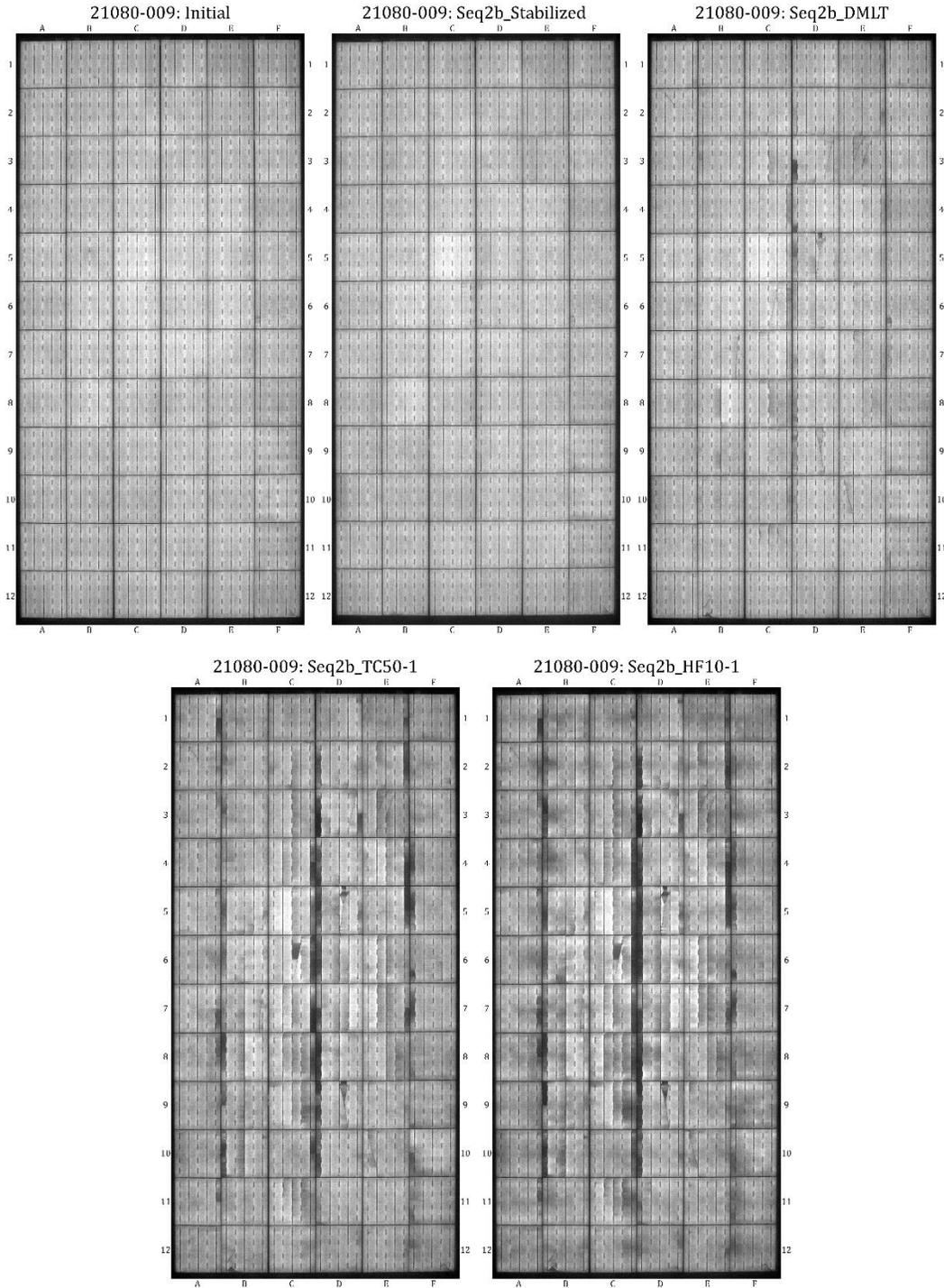
| Module ID | Reference  | Isc [A] | Voc [V] | Imp [A] | Vmp [V] | Pmp [W] |
|-----------|------------|---------|---------|---------|---------|---------|
| 21080-005 | Initial    | 1.993   | 46.02   | 1.890   | 39.35   | 74.36   |
|           | Stabilized | 2.000   | 45.97   | 1.884   | 39.29   | 74.03   |
|           | SMLT       | 1.992   | 45.34   | 1.718   | 37.05   | 63.64   |
|           | DMLT       | 1.997   | 45.58   | 1.800   | 38.20   | 68.75   |
|           | TC50       | 1.997   | 45.51   | 1.810   | 38.00   | 68.77   |
|           | HF10       | 1.979   | 45.49   | 1.780   | 37.86   | 67.39   |
| 21080-009 | Initial    | 1.996   | 46.08   | 1.889   | 39.40   | 74.42   |
|           | Stabilized | 2.007   | 45.96   | 1.882   | 39.21   | 73.79   |
|           | DMLT       | 1.992   | 45.91   | 1.851   | 39.01   | 72.20   |
|           | TC50       | 2.008   | 45.68   | 1.876   | 38.63   | 72.46   |
|           | HF10       | 1.978   | 45.64   | 1.845   | 38.55   | 71.14   |

## Electroluminescence Imaging

Module 21080-005 (Images taken at  $0.1 \times I_{sc}$  are provided separately in digital format)



Module 21080-009 (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 <sup>2</sup> ] | Pmp - Delta from Initial [%] |
|-----------|--------------|----------------------------------|------------------------------|
| 21080-005 | Stabilized   | 145.78                           | -0.66                        |
| 21080-009 | Stabilized   | 145.78                           | -0.75                        |
| 21080-002 | Z_Stabilized | 141.27                           | -0.62                        |

## Static Mechanical Loading

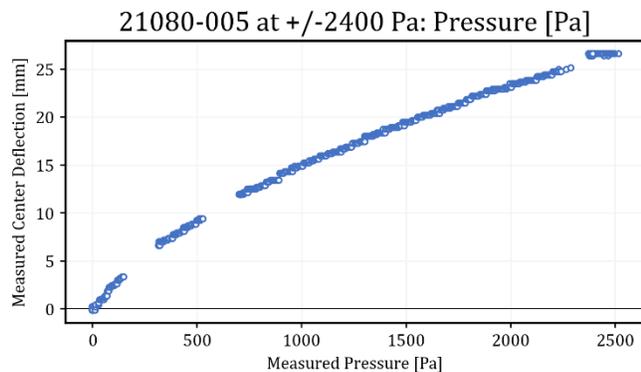
Pass/Fail also determined by follow-up MQT 01 Visual Inspection and MQT 15 Wet Leakage Current. Module was installed on the two support rails of the mechanical load tester running parallel to the module short-side. It was secured using industry standard 100 mm top clamps at the long-side quarter points.

| Module    | Test Reference | Cycle Count | Pressure - Down [Pa] | Pressure - Up [Pa] | Pass/Fail |
|-----------|----------------|-------------|----------------------|--------------------|-----------|
| 21080-005 | Seq2a_SMLT     | 3           | 2400                 | -2400              | Pass      |

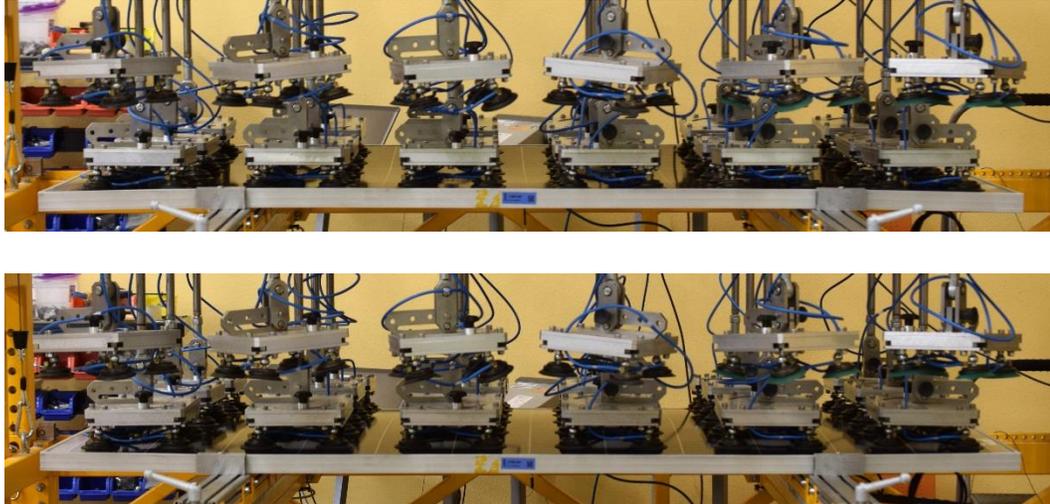
### Module 21080-005

#### Pressure vs Deflection Plot and Data

| Pressure [Pa] | Deflection [mm] | Deflection [in] |
|---------------|-----------------|-----------------|
| 0             | 0.00            | 0.00            |
| 200           | 2.90            | 0.11            |
| 400           | 7.54            | 0.30            |
| 600           | 9.38            | 0.37            |
| 800           | 12.59           | 0.50            |
| 1000          | 14.96           | 0.59            |
| 1200          | 16.74           | 0.66            |
| 1400          | 18.61           | 0.73            |
| 1600          | 20.19           | 0.80            |
| 1800          | 21.83           | 0.86            |
| 2000          | 23.33           | 0.92            |
| 2200          | 24.51           | 0.97            |
| 2400          | 26.61           | 1.05            |



## Module Deflection Images at Maximum Downward (Top) and Upward Loads (Bottom)



### Cyclic (Dynamic) Mechanical Loading

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

| Module    | Test Reference | Cycle Count | Pressure - High [Pa] | Pressure - Low [Pa] | Pass/Fail |
|-----------|----------------|-------------|----------------------|---------------------|-----------|
| 21080-005 | Seq2a_DMLT     | 1000        | 1000                 | -1000               | Pass      |
| 21080-009 | Seq2b_DMLT     | 1000        | 1000                 | -1000               | Pass      |

### Thermal Cycling

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

| Module    | Test Reference | Cycle Count | Total Cycle Count | Temp - High [°C] | Temp - Low [°C] | Pass/Fail |
|-----------|----------------|-------------|-------------------|------------------|-----------------|-----------|
| 21080-005 | Seq2a_TC50     | 50          | 50                | 85               | -40             | Pass      |
| 21080-009 | Seq2b_TC50     | 50          | 50                | 85               | -40             | Pass      |

## Humidity Freeze

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

| Module    | Test Reference | Cycle Count | Total Cycle Count | Temp - High [°C] | Temp - Low [°C] | Humidity [% RH] | Pass/Fail |
|-----------|----------------|-------------|-------------------|------------------|-----------------|-----------------|-----------|
| 21080-005 | Seq2a_HF10     | 10          | 10                | 85               | -40             | 85              | Pass      |
| 21080-009 | Seq2b_HF10     | 10          | 10                | 85               | -40             | 85              | Pass      |

## Procedures

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

| Test Name                                  | Standard / Procedure      | CFV Accreditation |
|--|---------------------------|-------------------|
| <b>Incoming Inspection</b>                 | CFV                       | NA                |
| <b>Visual Inspection</b>                   | IEC 61215-2:2016 MQT 01   | ISO 17025         |
| <b>Electroluminescence Imaging</b>         | IEC TS 60904-13:2018      | ISO 17025         |
| <b>Preconditioning</b>                     | IEC 61215-2:2016 MQT 19   | ISO 17025         |
| <b>Performance at STC</b>                  | IEC 61215-2:2016 MQT 06.1 | ISO 17025         |
| <b>Performance at Low Irradiance</b>       | IEC 61215-2:2016 MQT 07   | ISO 17025         |
| <b>Wet Leakage Current</b>                 | IEC 61215-2:2016 MQT 15   | ISO 17025         |
| <b>Insulation</b>                          | IEC 61215-2:2016 MQT 03   | ISO 17025         |
| <b>Static Mechanical Loading</b>           | IEC 61215-2:2016 MQT 16   | ISO 17025         |
| <b>Cyclic (Dynamic) Mechanical Loading</b> | IEC TS 62782:2016         | ISO 17025         |
| <b>Thermal Cycling</b>                     | IEC 61215-2:2016 MQT 11   | ISO 17025         |
| <b>Humidity Freeze</b>                     | IEC 61215-2:2016 MQT 12   | ISO 17025         |

## Equipment Calibration Information

Equipment and Calibration information is available upon request.

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--END OF REPORT--