

## 24095 Test Report: Mechanical, Thermal and Humidity Stress Testing and Comparison of D2 Solar Custom Backsheet and Control Modules for Osazda

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**Project ID:** 24095 (CFV), 20240249 (Customer Signed Quote)  
**Customer:** Sang M Han/Osazda  
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## Project Summary

CFV Labs conducted mechanical, thermal and humidity stress testing according to IEC 61215-2:2021 on ten custom modules produced by D2 Solar and provided by Osazda. Half of the modules provided contained carbon nanotube embedded into a silver paste used to form the electrodes on the cells, created by Osazda. This version of the paste is called MetZilla PERC 01, Module Number: MZ22-10. These modules will be referred to as 'OSA' throughout the report. The remaining five modules did not have OSA paste and were used as controls.

Testing was divided into three test legs – Mechanical Stress, Thermal Stress, Humidity Stress. The Mechanical stress leg consisted of MQT 16 Static Mechanical Loading (SMLT), MQT 20 Dynamic Mechanical Loading (DMLT), 50 cycles of MQT 11 Thermal Cycling (TC50), and 10 cycles of MQT 12 Humidity Freeze (HF10). The thermal stress leg consisted of 600 cycles of MQT 11 Thermal Cycling (TC600). The humidity stress leg consisted of 2000 hours of MQT13 Damp Heat (DH2000). Each test leg included performance and safety testing at pre, interim, and post testing stages.

**Mechanical Stress:** The average change in Pmp from stabilized to post-mechanical stress was measured to be  $-0.29\%$  and  $-1.70\%$  for the OSA and control modules respectively. The average change in Pmp from stabilized to post-humidity freeze stress was measured to be  $-2.39\%$  and  $-3.53\%$  for the OSA and control modules respectively. During safety testing, one OSA and one control module failed wet leakage testing following DMLT (OSA) and HF10 (control).

**Thermal Stress:** The average change in Pmp from stabilized to post-thermal stress was measured to be  $-2.59\%$  and  $-1.88\%$  for the OSA and control modules respectively. The modules passed all initial, interim, and final safety tests.

**Humidity Stress:** The average change in Pmp from stabilized to post-humidity stress was measured to be  $-1.56\%$  and  $-2.12\%$  for the OSA and control modules respectively. The modules passed all initial, interim, and final safety tests.

CFV's measurement repeatability for this technology type is  $\pm 0.50\%$ .

The tables below show the average performance results divided by test leg and module type.

*Front-side Measurements (1000 W/m<sup>2</sup>, 25 °C):*

OSA Cell/Control	Reference	Isc [A]	Voc [V]	Imp [A]	Vmp [V]	Pmp [W]	FF [%]
OSA (Thermal Stress)	2_TS0_Initial	9.613	39.84	9.117	32.84	299.43	78.19
	2_TS0_Stabilized	9.589	39.90	9.101	32.96	299.99	78.42
	2_TS1_TC200	9.571	39.88	9.073	32.65	296.23	77.62
	2_TS2_TC200	9.553	39.89	9.056	32.72	296.34	77.77
	2_TS3_TC200	9.442	39.87	8.932	32.72	292.22	77.64
Control (Thermal Stress)	2_TS0_Initial	9.880	40.07	9.289	32.40	300.93	76.01
	2_TS0_Stabilized	9.874	40.17	9.297	32.51	302.24	76.21
	2_TS1_TC200	9.856	40.18	9.271	32.47	301.00	76.01
	2_TS2_TC200	9.843	40.09	9.242	32.37	299.16	75.83
	2_TS3_TC200	9.721	40.19	9.141	32.45	296.56	75.91
OSA (Mechanical Stress)	1_TS0_Initial	9.643	39.95	9.166	33.03	302.70	78.59
	1_TS0_Stabilized	9.627	39.97	9.145	33.08	302.44	78.61
	1_TS2_CMLT	9.608	40.01	9.104	33.13	301.59	78.45
	1_TS4_HF10	9.450	39.89	8.959	32.96	295.23	78.32
Control (Mechanical Stress)	1_TS0_Initial	9.898	40.12	9.336	32.56	303.93	76.54
	1_TS0_Stabilized	9.881	40.16	9.341	32.59	304.36	76.70
	1_TS2_CMLT	9.857	40.07	9.224	32.44	299.19	75.76
	1_TS4_HF10	9.704	40.08	9.060	32.41	293.60	75.50
OSA (Humidity Stress)	3_TS0_Initial	9.608	39.88	9.132	32.91	300.55	78.44
	3_TS0_Stabilized	9.588	39.96	9.093	33.07	300.65	78.47
	3_TS1_DH1000	9.533	39.81	9.042	32.88	297.26	78.33
	3_TS2_DH1000	9.489	39.85	8.998	32.89	295.96	78.27
Control (Humidity Stress)	3_TS0_Initial	9.849	40.05	9.303	32.40	301.41	76.41
	3_TS0_Stabilized	9.821	40.12	9.306	32.55	302.87	76.87
	3_TS1_DH1000	9.805	39.95	9.283	32.18	298.70	76.26
	3_TS2_DH1000	9.761	39.99	9.218	32.16	296.44	75.95

*Front-side Change from Baseline:*

Module ID	Reference	$\Delta I_{sc}$ [%]	$\Delta V_{oc}$ [%]	$\Delta I_{mp}$ [%]	$\Delta V_{mp}$ [%]	$\Delta P_{mp}$ [%]
OSA (Thermal Stress)	2_TS0_Initial	+0.25	-0.16	+0.18	-0.36	-0.19
	2_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	2_TS1_TC200	-0.19	-0.03	-0.31	-0.94	-1.25
	2_TS2_TC200	-0.37	-0.03	-0.49	-0.73	-1.22
	2_TS3_TC200	-1.53	-0.08	-1.86	-0.74	-2.59
Control (Thermal Stress)	2_TS0_Initial	+0.06	-0.24	-0.09	-0.34	-0.44
	2_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	2_TS1_TC200	-0.19	+0.04	-0.28	-0.13	-0.42
	2_TS2_TC200	-0.32	-0.20	-0.59	-0.43	-1.02
	2_TS3_TC200	-1.56	+0.07	-1.68	-0.20	-1.88
OSA (Mechanical Stress)	1_TS0_Initial	+0.17	-0.06	+0.24	-0.15	+0.09
	1_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	1_TS2_CMLT	-0.20	+0.11	-0.44	+0.16	-0.29
	1_TS4_HF10	-1.84	-0.20	-2.04	-0.37	-2.39
Control (Mechanical Stress)	1_TS0_Initial	+0.17	-0.10	-0.05	-0.09	-0.14
	1_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	1_TS2_CMLT	-0.25	-0.24	-1.25	-0.46	-1.70
	1_TS4_HF10	-1.80	-0.21	-3.01	-0.54	-3.53
OSA (Humidity Stress)	3_TS0_Initial	+0.20	-0.21	+0.43	-0.46	-0.03
	3_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	3_TS1_DH1000	-0.58	-0.38	-0.56	-0.57	-1.13
	3_TS2_DH1000	-1.04	-0.29	-1.04	-0.52	-1.56
Control (Humidity Stress)	3_TS0_Initial	+0.29	-0.17	-0.03	-0.46	-0.48
	3_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	3_TS1_DH1000	-0.17	-0.42	-0.25	-1.13	-1.38
	3_TS2_DH1000	-0.61	-0.33	-0.94	-1.19	-2.12

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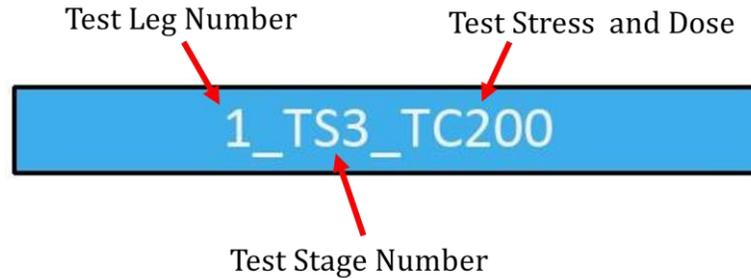
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## Test Flow

The figure below shows the test flow for this project.

Seq0 Incoming Inspection	Seq1 Mechanical Stress Sequence	Seq2 Thermal Stress Sequence	Seq3 Humidity Stress Sequence
10 Samples	4 Samples	4 Samples	2 Samples
@S0_T0_Initial	@1_TS0_Initial	@2_TS0_Initial	@3_TS0_Initial
Incoming Inspection	MQT 06.1 Perf at STC-V1 - 2021 - Front	MQT 06.1 Perf at STC-V1 - 2021 - Front	MQT 06.1 Perf at STC-V1 - 2021 - Front
MQT 01 Visual Inspection - 2021	EL Imaging 1.0x Isc	EL Imaging 1.0x Isc	EL Imaging 1.0x Isc
	@1_TS0_Stabilized	@2_TS0_Stabilized	@3_TS0_Stabilized
	Custom Outdoor Exposure (40kWh, OC)	Custom Outdoor Exposure (40kWh, OC)	Custom Outdoor Exposure (40kWh, OC)
	MQT 06.1 Perf at STC-V1 - 2021 - Front	MQT 06.1 Perf at STC-V1 - 2021 - Front	MQT 06.1 Perf at STC-V1 - 2021 - Front
	MQT 03 Insulation - 2021	MQT 03 Insulation - 2021	MQT 03 Insulation - 2021
	MQT 15 Wet Leakage Current - 2021	MQT 15 Wet Leakage Current - 2021	MQT 15 Wet Leakage Current - 2021
	@1_TS1_SMLT	@2_TS1_TC200	@3_TS1_DH1000
	MQT 16 Static Mechanical Load - 2021	MQT 11 Thermal Cycling - 2021 (200 Cycles)	MQT 13 Damp Heat - 2021 (1000 hours)
	@1_TS2_CMLT	MQT 01 Visual Inspection - 2021	MQT 01 Visual Inspection - 2021
	Cyclic Mechanical Loading	MQT 06.1 Perf at STC-V1 - 2021 - Front	MQT 06.1 Perf at STC-V1 - 2021 - Front
	MQT 01 Visual Inspection - 2021	EL Imaging 1.0x Isc	EL Imaging 1.0x Isc
	MQT 06.1 Perf at STC-V1 - 2021 - Front	@2_TS2_TC200	@3_TS2_DH1000
	EL Imaging 1.0x Isc	MQT 11 Thermal Cycling - 2021 (200 Cycles)	MQT 13 Damp Heat - 2021 (1000 hours)
	MQT 03 Insulation - 2021	MQT 01 Visual Inspection - 2021	MQT 01 Visual Inspection - 2021
	MQT 15 Wet Leakage Current - 2021	MQT 06.1 Perf at STC-V1 - 2021 - Front	MQT 06.1 Perf at STC-V1 - 2021 - Front
	@1_TS3_TC50	EL Imaging 1.0x Isc	EL Imaging 1.0x Isc
	MQT 11 Thermal Cycling - 2021 (50 Cycles)	@2_TS3_TC200	MQT 03 Insulation - 2021
	@1_TS4_HF10	MQT 11 Thermal Cycling - 2021 (200 Cycles)	MQT 15 Wet Leakage Current - 2021
	MQT 12 Humidity Freeze - 2021	MQT 01 Visual Inspection - 2021	
	MQT 01 Visual Inspection - 2021	MQT 06.1 Perf at STC-V1 - 2021 - Front	
	MQT 06.1 Perf at STC-V1 - 2021 - Front	EL Imaging 1.0x Isc	
	EL Imaging 1.0x Isc	MQT 03 Insulation - 2021	
	MQT 03 Insulation - 2021	MQT 15 Wet Leakage Current - 2021	

In the diagram above the test flow is divided into columns, which are referred to as “test legs”. Each test leg is graphically displayed under the dark blue title blocks with comments in the gray block under the title block. Within each test leg, individual tests are displayed as white blocks. Tests are divided into groups, named “references”. References are displayed as light blue blocks. References are used to separate and identify results that are performed at different stages of testing (see below).



Test Stress and Dose sums based on the Test Stage Number. For example, 1\_TS3\_TC200 stipulates that in Test Leg 1, 200 cycles of Thermal Cycling were applied in Test Stage Number 3. If that is followed by 1\_TS4\_TC200, another 200 cycles were applied, summing to 400 total thermal cycles that have been applied by TS4.”

*Test Flow Assignment:*

Module ID	Test Leg[s]	Control or OSA Cell
24095-001	Seq0 Incoming Inspection, Seq2 Thermal Stress Sequence	OSA
24095-002	Seq0 Incoming Inspection, Seq2 Thermal Stress Sequence	OSA
24095-003	Seq0 Incoming Inspection, Seq2 Thermal Stress Sequence	Control
24095-004	Seq0 Incoming Inspection, Seq2 Thermal Stress Sequence	Control
24095-005	Seq0 Incoming Inspection, Seq1 Mechanical Stress Sequence	OSA
24095-006	Seq0 Incoming Inspection, Seq1 Mechanical Stress Sequence	OSA
24095-007	Seq0 Incoming Inspection, Seq1 Mechanical Stress Sequence	Control
24095-008	Seq0 Incoming Inspection, Seq1 Mechanical Stress Sequence	Control
24095-009	Seq0 Incoming Inspection, Seq3 Humidity Stress Sequence	OSA
24095-010	Seq0 Incoming Inspection, Seq3 Humidity Stress Sequence	Control

## Results

### Incoming Inspection

No issues were observed on the test modules during the Incoming Inspection. An Incoming Inspection report is provided separately.

### MQT 01 Visual Inspection

The results of the visual inspection are summarized in the table below. The presence of any of the following observations constitutes a major visual defect:

- (a) Broken, cracked, or torn external surfaces.
- (b) Bent or misaligned external surfaces, including superstrates, substrates, frames and junction boxes to the extent that the operation of the PV module would be impaired.
- (c) Bubbles or delaminations forming a continuous path between electric circuit and the edge of the module.
- (d) If the mechanical integrity depends on lamination or other means of adhesion, the sum of the area of all bubbles shall not exceed 1 % of the total module area.
- (e) Evidence of any molten or burned encapsulant, backsheet, frontsheet, diode or active PV component.
- (f) Loss of mechanical integrity to the extent that the installation and operation of the module would be impaired.
- (g) Cracked/broken cells which can remove more than 10 % of the cell's photovoltaic active area from the electrical circuit of the PV module.
- (h) Voids in, or visible corrosion of any of the layers of the active (live) circuitry of the module extending over more than 10 % of any cell.
- (i) Broken interconnections, joints or terminals.
- (j) Any short-circuited live parts or exposed live electrical parts.
- (k) Module markings (label) are no longer attached, or the information is unreadable.

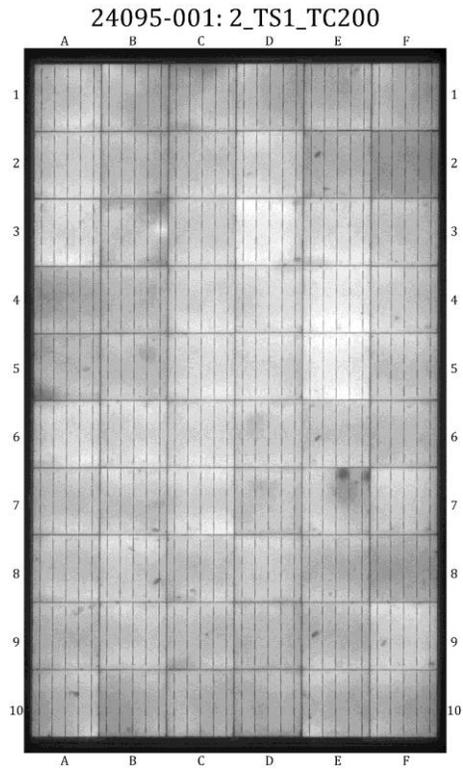
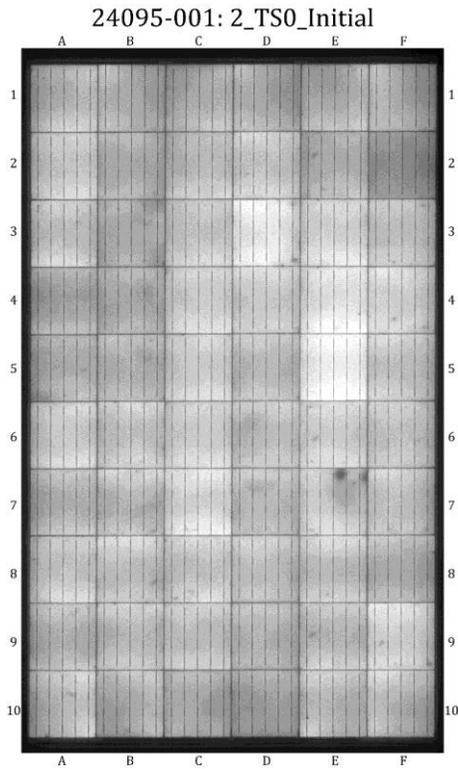
No major visual defects were observed during the visual inspection of the tested modules. The results are summarized in the table below.

Module ID	Reference	Result	Major Defect Found?	Defect	Comments
24095-001 (OSA)	S0_T0_Initial	Complete	No	k	No nameplate
	2_TS1_TC200	Complete	No	k	No nameplate
	2_TS2_TC200	Complete	No	k	No nameplate
	2_TS3_TC200	Complete	No	k	No nameplate
24095-002 (OSA)	S0_T0_Initial	Complete	No	k	No nameplate
	2_TS1_TC200	Complete	No	k	No nameplate
	2_TS2_TC200	Complete	No	k	No nameplate
	2_TS3_TC200	Complete	No	k	No nameplate
24095-003 (Control)	S0_T0_Initial	Complete	No	k	No nameplate
	2_TS1_TC200	Complete	No	k	No nameplate
	2_TS2_TC200	Complete	No	k	No nameplate
	2_TS3_TC200	Complete	No	k	No nameplate
24095-004 (Control)	S0_T0_Initial	Complete	No	k	No nameplate
	2_TS1_TC200	Complete	No	k	No nameplate
	2_TS2_TC200	Complete	No	k	No nameplate
	2_TS3_TC200	Complete	No	k	No nameplate
24095-005 (OSA)	S0_T0_Initial	Complete	No	k	No nameplate
	1_TS2_CMLT	Complete	No	k	No nameplate
	1_TS4_HF10	Complete	No	k	No nameplate
24095-006 (OSA)	S0_T0_Initial	Complete	No	k	No nameplate
	1_TS2_CMLT	Complete	No	k	No nameplate
	1_TS4_HF10	Complete	No	k	No nameplate
24095-007 (Control)	S0_T0_Initial	Complete	No	k	No nameplate
	1_TS2_CMLT	Complete	No	k	No nameplate
	1_TS4_HF10	Complete	No	k	No nameplate
24095-008 (Control)	S0_T0_Initial	Complete	No	k	No nameplate
	1_TS2_CMLT	Complete	No	k	No nameplate
	1_TS4_HF10	Complete	No	k	No nameplate
24095-009 (OSA)	S0_T0_Initial	Complete	No	k	No nameplate
	3_TS1_DH1000	Complete	No	k	No nameplate
	3_TS2_DH1000	Complete	No	k	No nameplate
24095-010 (Control)	S0_T0_Initial	Complete	No	k	No nameplate
	3_TS1_DH1000	Complete	No	k	No nameplate
	3_TS2_DH1000	Complete	No	k	No nameplate

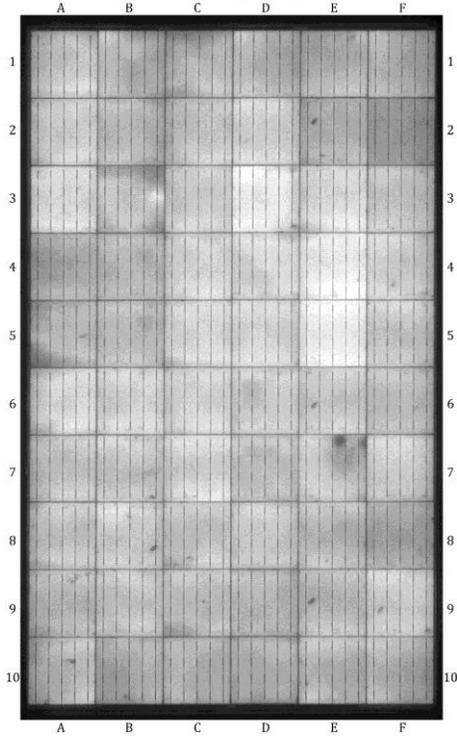
## Electroluminescence (EL) Imaging - 1.0xIsc

Full resolution EL images are provided to the customer separately in digital format.

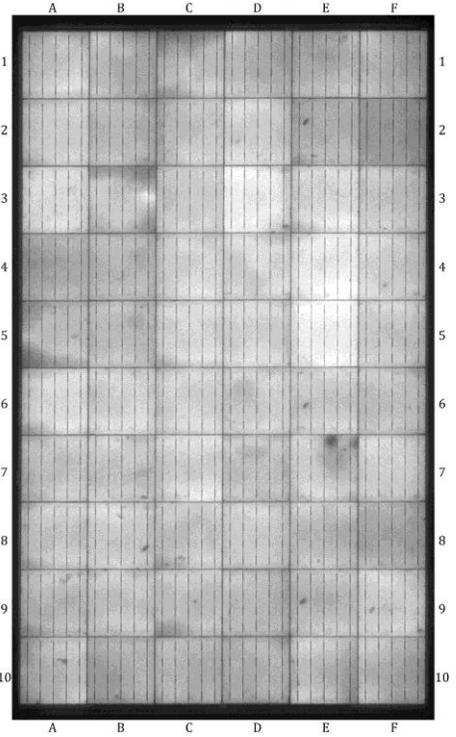
### *Thermal Stress Leg: OSA Modules*



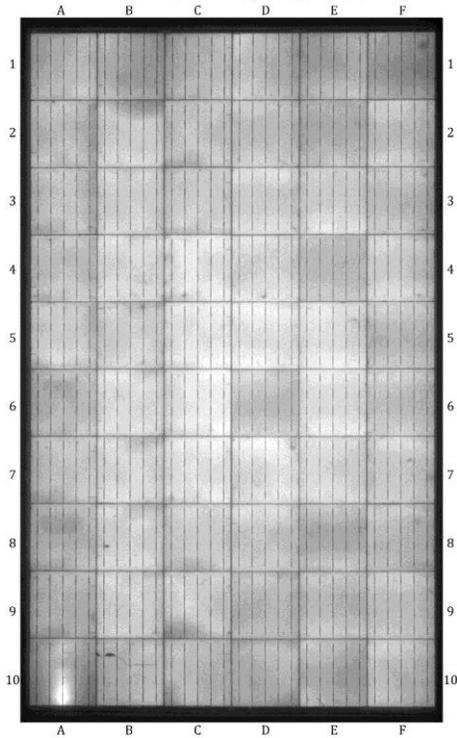
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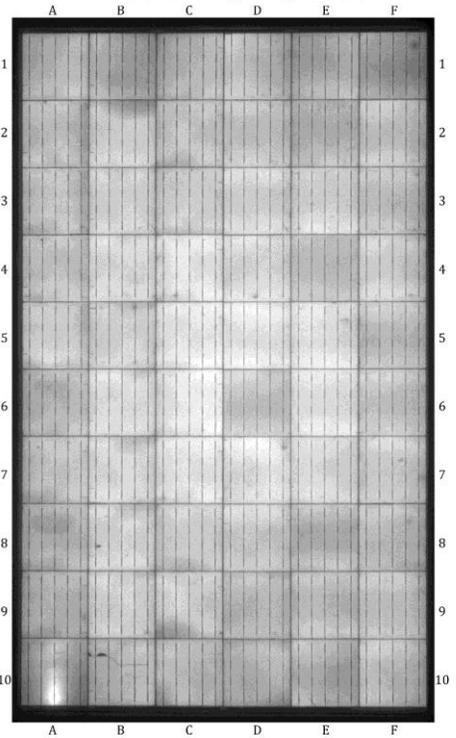
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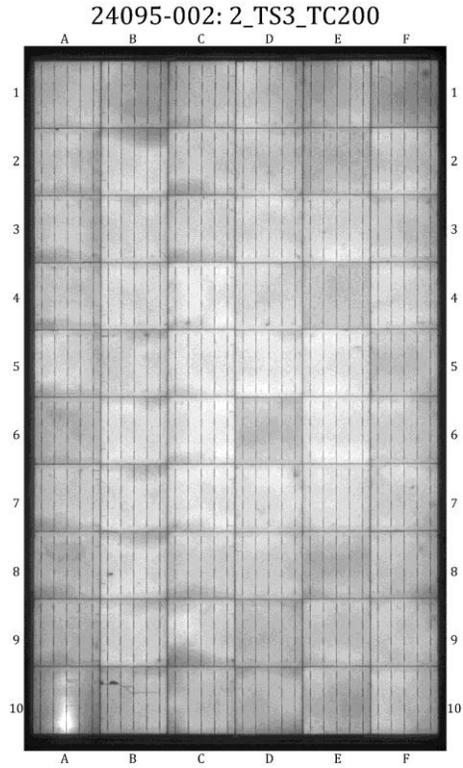
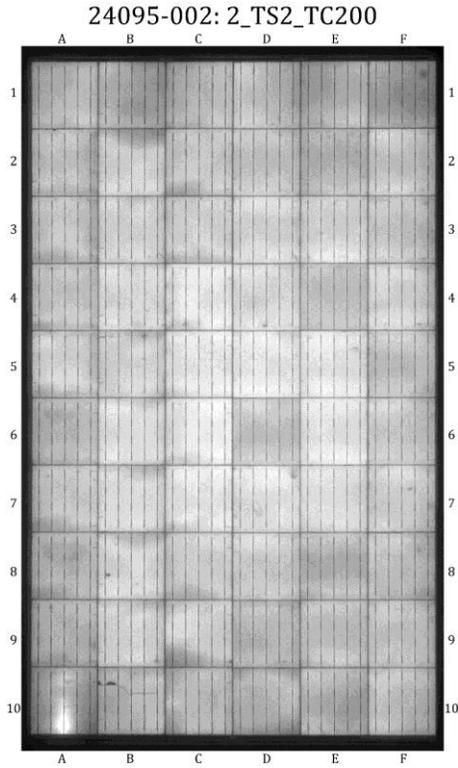


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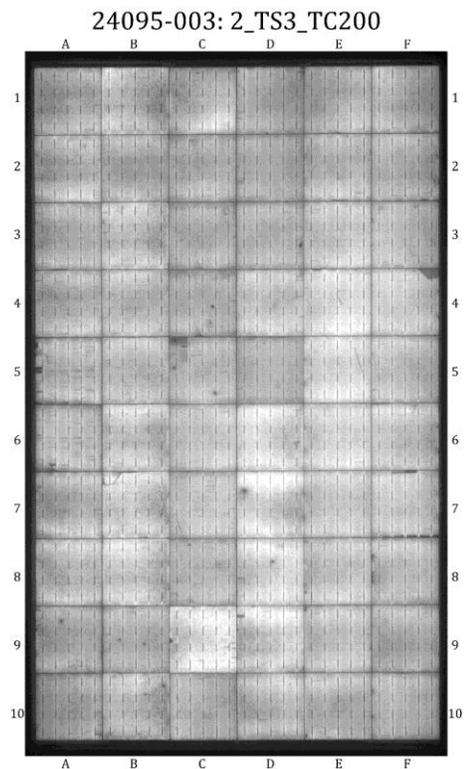
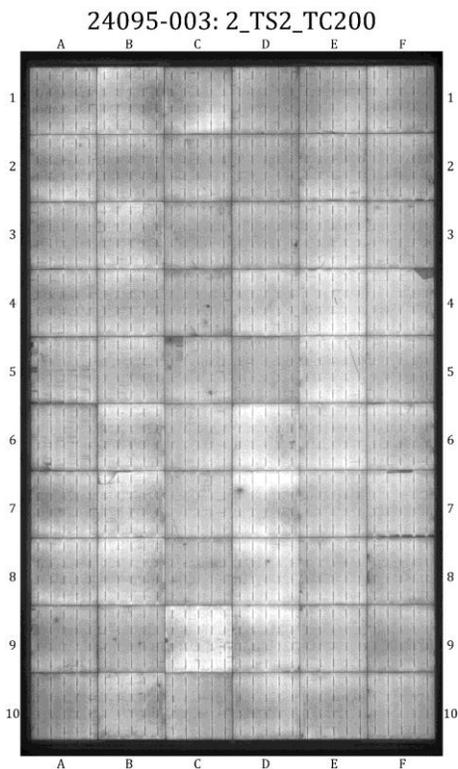
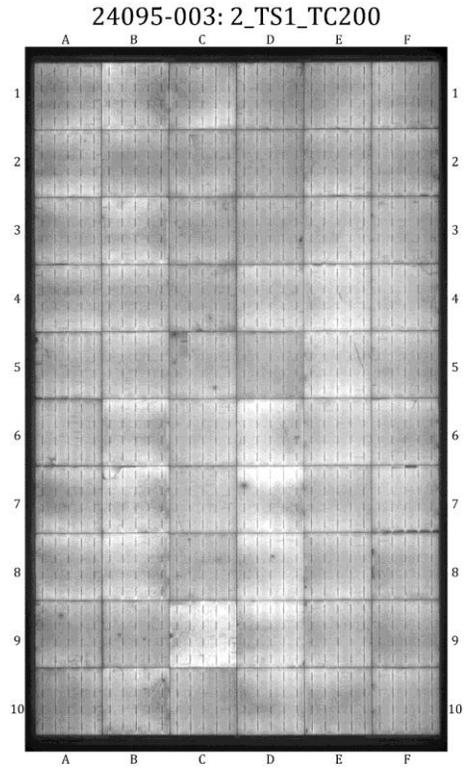
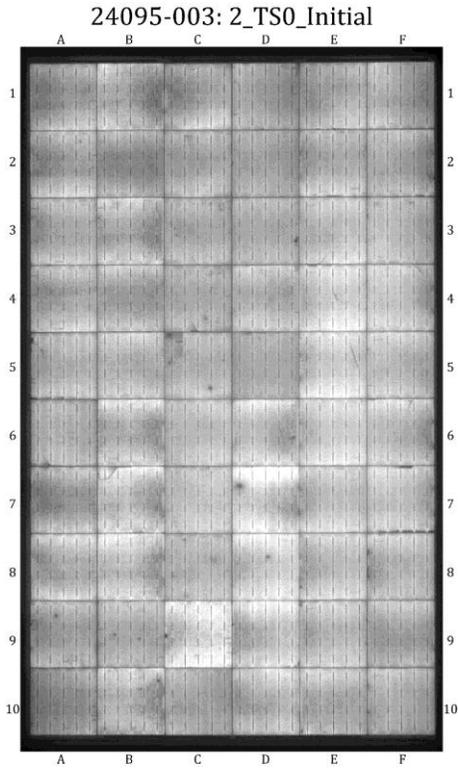


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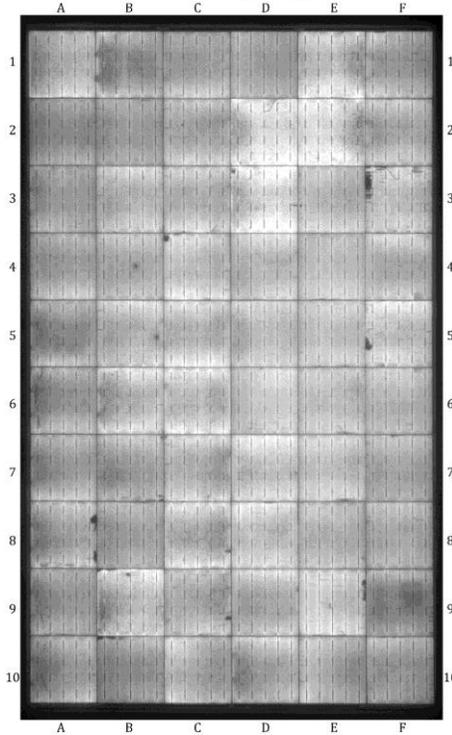




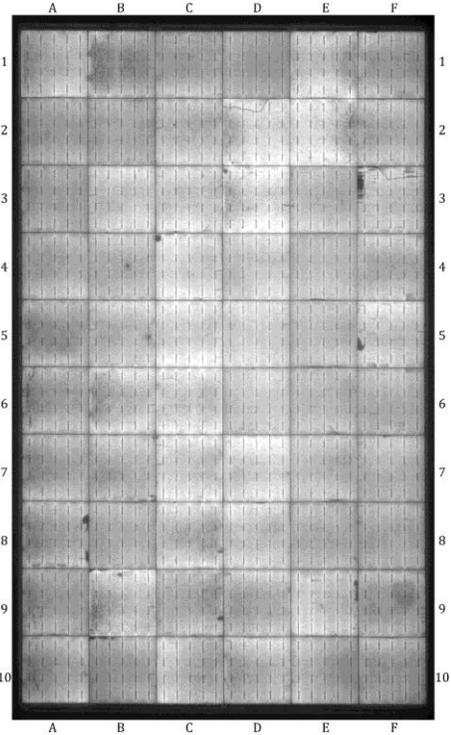
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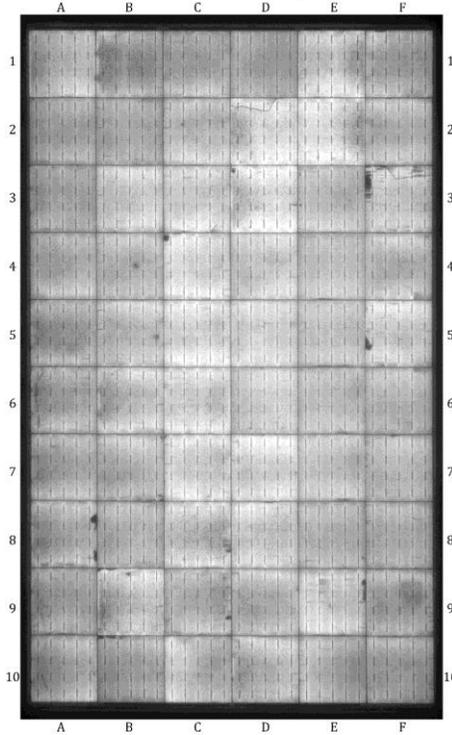
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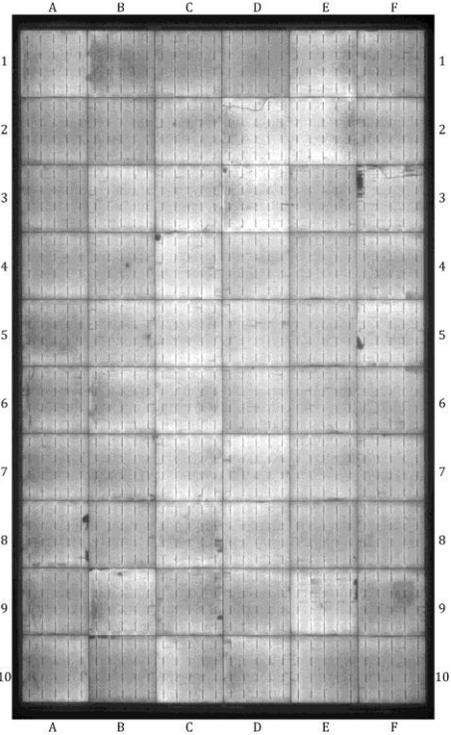
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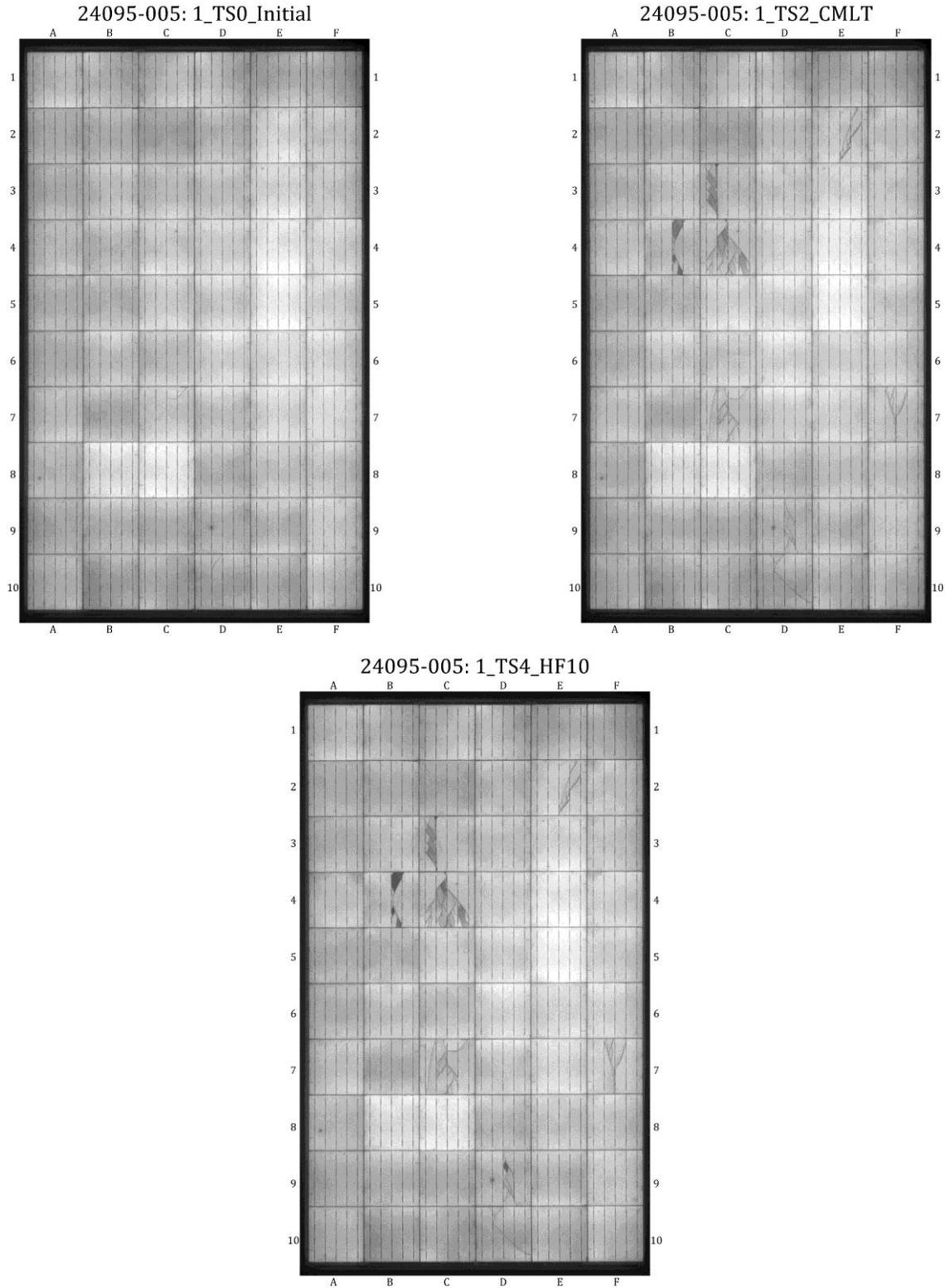
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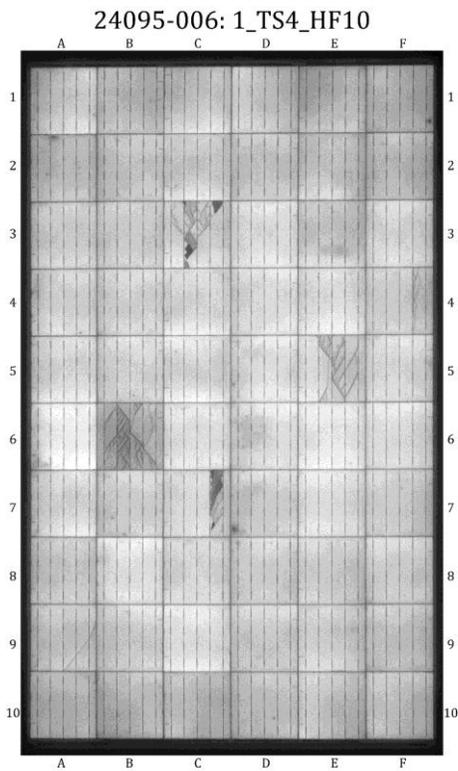
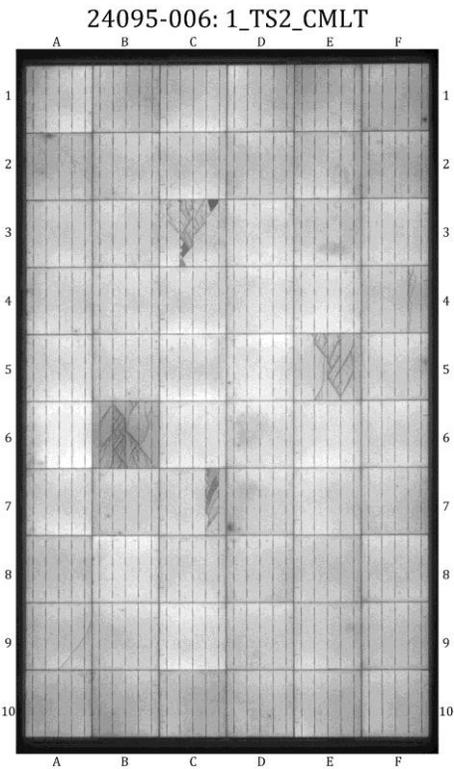
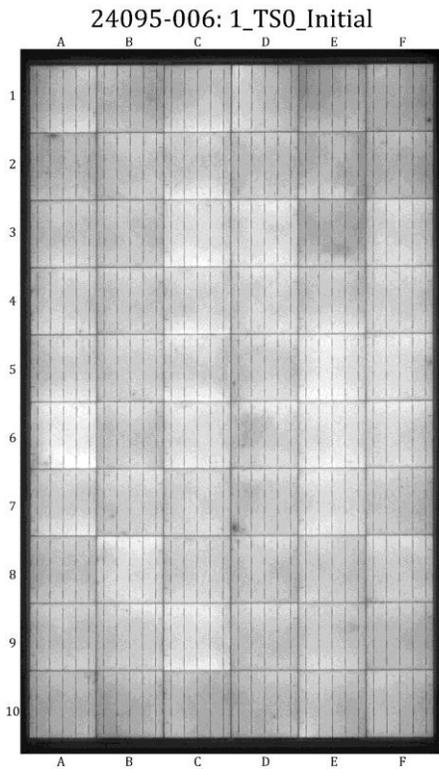


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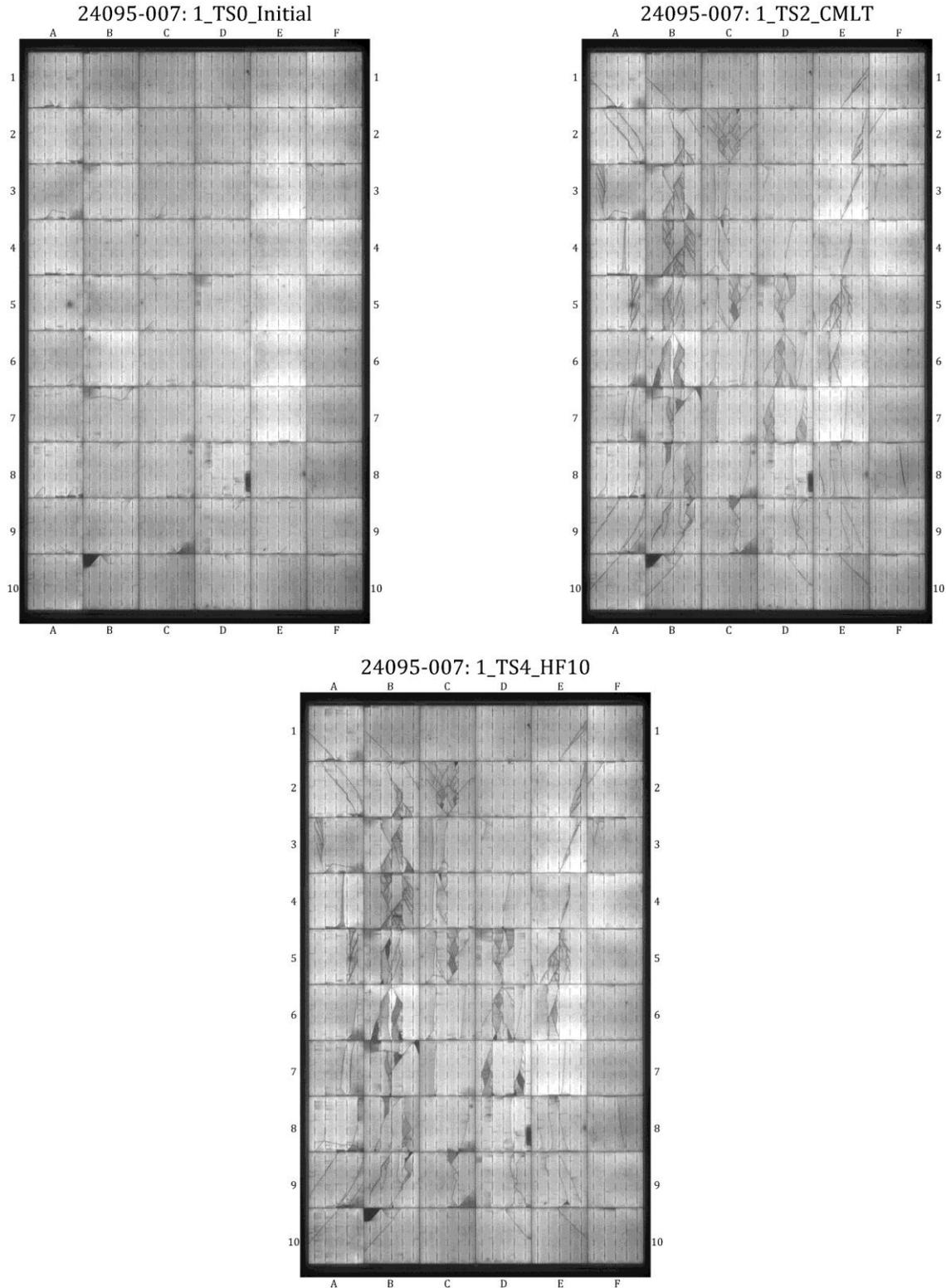


## Mechanical Stress Leg: OSA Modules

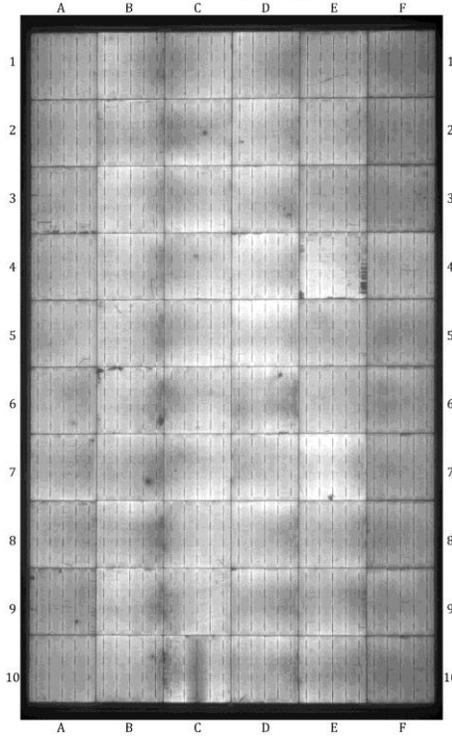




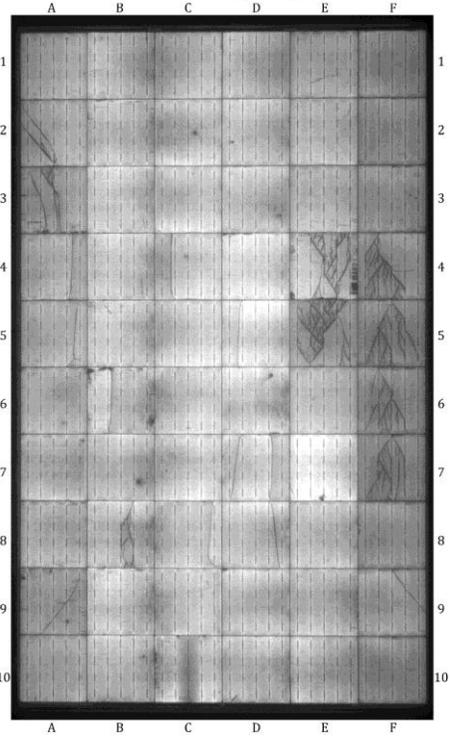
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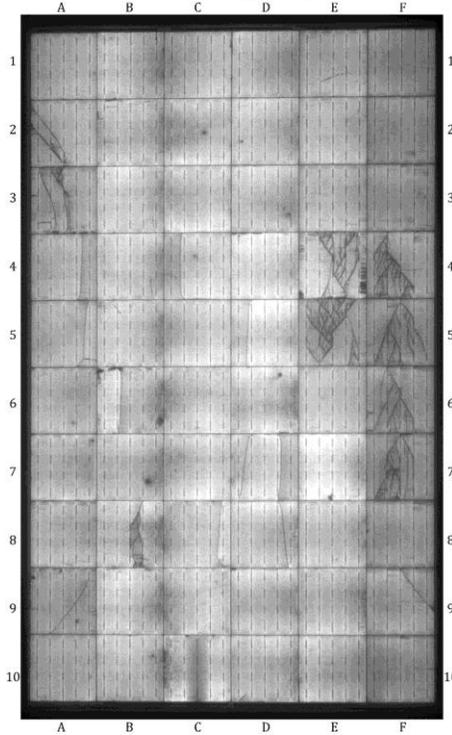
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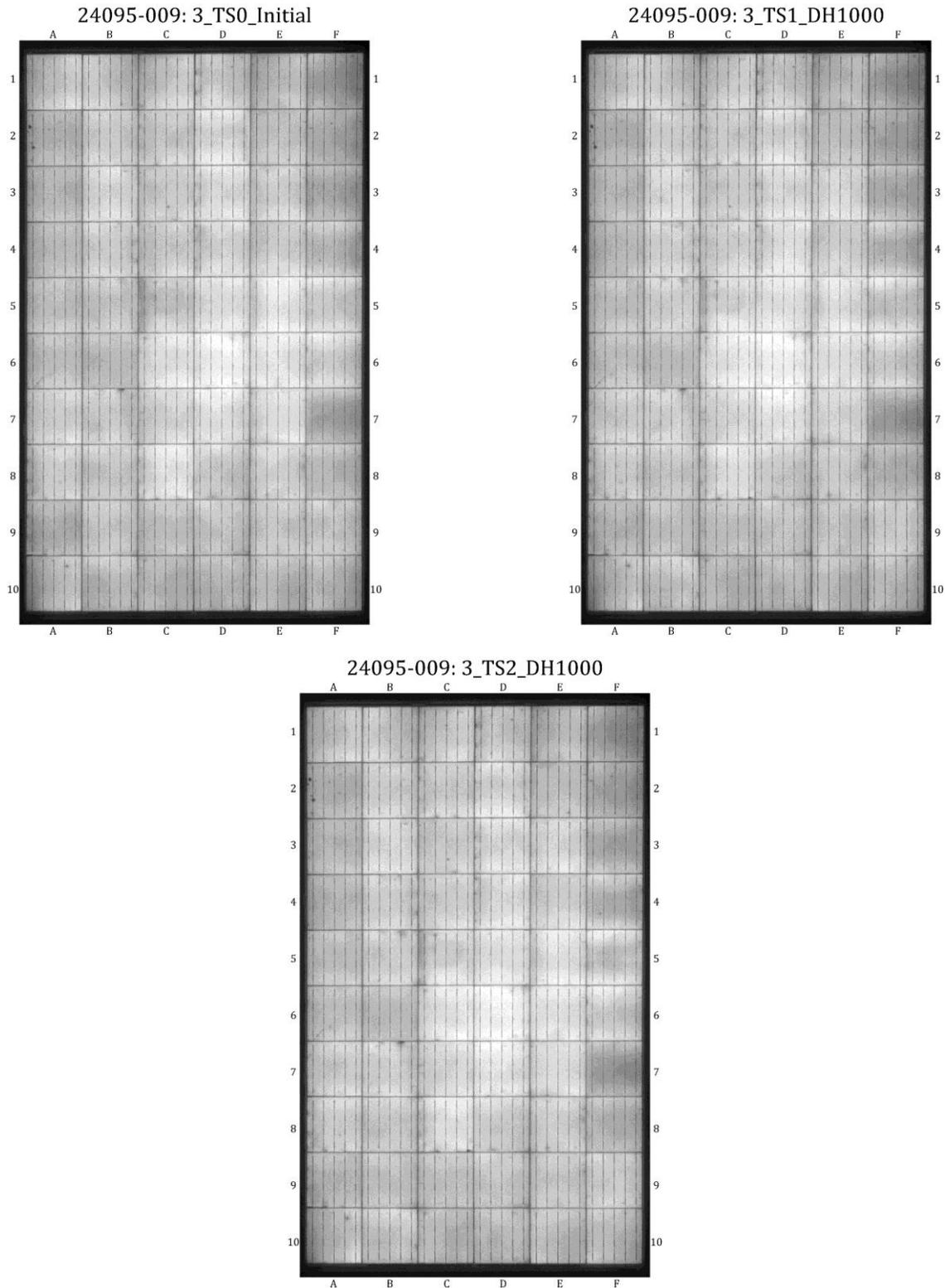
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24095-008: 1\_TS4\_HF10

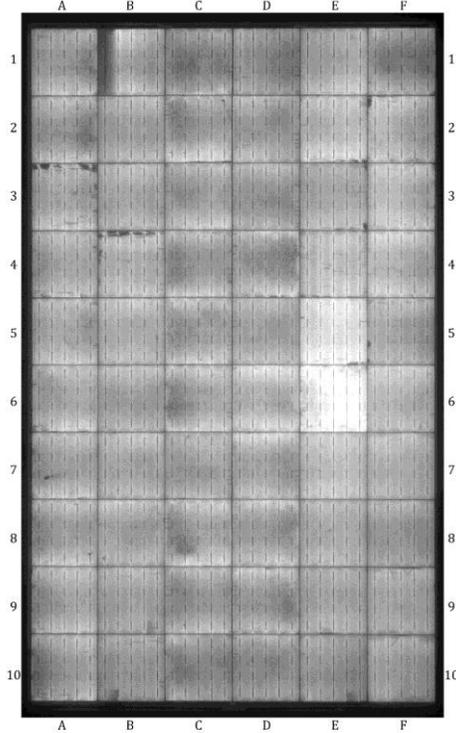


## Humidity Stress Leg: OSA Modules

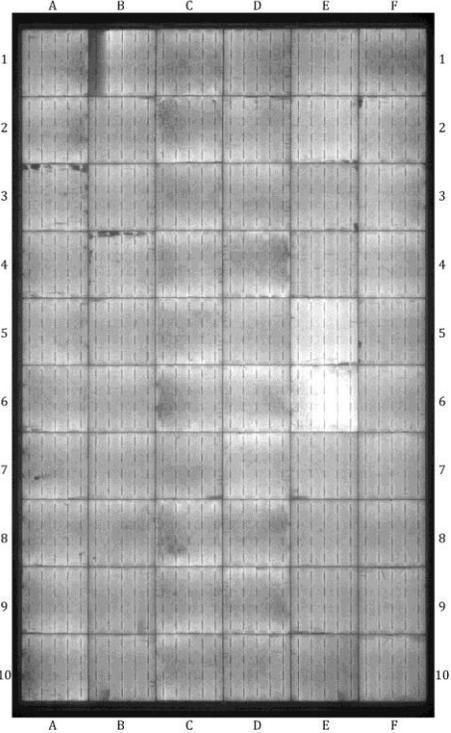


## Humidity Stress Leg: Control Modules

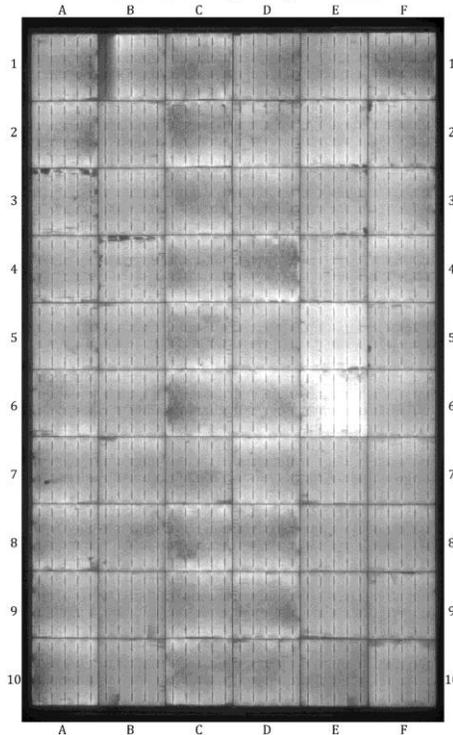
24095-010: 3\_TS0\_Initial



24095-010: 3\_TS1\_DH1000



24095-010: 3\_TS2\_DH1000



## MQT 06.1 Performance at STC

Front-side Measurements (1000 W/m<sup>2</sup>, 25 °C):

Module ID	Reference	Isc [A]	Voc [V]	Imp [A]	Vmp [V]	Pmp [W]	FF [%]
24095-001 (OSA)	2_TS0_Initial	9.583	39.75	9.089	32.81	298.25	78.29
	2_TS0_Stabilized	9.556	39.82	9.079	32.93	298.99	78.58
	2_TS1_TC200	9.541	39.79	9.058	32.78	296.93	78.21
	2_TS2_TC200	9.519	39.85	9.050	32.80	296.89	78.27
	2_TS3_TC200	9.408	39.77	8.914	32.80	292.39	78.14
24095-002 (OSA)	2_TS0_Initial	9.642	39.92	9.145	32.87	300.61	78.09
	2_TS0_Stabilized	9.621	39.97	9.123	32.99	300.98	78.26
	2_TS1_TC200	9.600	39.97	9.087	32.52	295.52	77.02
	2_TS2_TC200	9.587	39.93	9.062	32.64	295.78	77.27
	2_TS3_TC200	9.475	39.96	8.949	32.63	292.05	77.14
24095-003 (Control)	2_TS0_Initial	9.904	40.09	9.295	32.46	301.71	75.98
	2_TS0_Stabilized	9.904	40.17	9.322	32.52	303.13	76.19
	2_TS1_TC200	9.891	40.18	9.297	32.47	301.84	75.94
	2_TS2_TC200	9.878	40.06	9.258	32.28	298.88	75.53
	2_TS3_TC200	9.743	40.20	9.163	32.45	297.32	75.90
24095-004 (Control)	2_TS0_Initial	9.855	40.05	9.282	32.34	300.14	76.03
	2_TS0_Stabilized	9.844	40.16	9.271	32.50	301.35	76.23
	2_TS1_TC200	9.821	40.18	9.245	32.47	300.16	76.07
	2_TS2_TC200	9.807	40.11	9.225	32.46	299.43	76.12
	2_TS3_TC200	9.698	40.18	9.118	32.44	295.80	75.91
24095-005 (OSA)	1_TS0_Initial	9.670	39.97	9.192	33.01	303.40	78.50
	1_TS0_Stabilized	9.642	39.96	9.165	33.06	303.01	78.65
	1_TS2_CMLT	9.643	40.01	9.122	33.13	302.20	78.32
	1_TS4_HF10	9.494	39.90	8.981	32.94	295.80	78.08
24095-006 (OSA)	1_TS0_Initial	9.616	39.92	9.140	33.04	302.00	78.67
	1_TS0_Stabilized	9.612	39.98	9.124	33.09	301.87	78.56
	1_TS2_CMLT	9.572	40.01	9.085	33.13	300.97	78.58
	1_TS4_HF10	9.406	39.88	8.936	32.97	294.65	78.55
24095-007 (Control)	1_TS0_Initial	9.902	40.15	9.360	32.67	305.80	76.92
	1_TS0_Stabilized	9.885	40.17	9.363	32.68	305.96	77.05
	1_TS2_CMLT	9.852	40.07	9.214	32.52	299.67	75.91
	1_TS4_HF10	9.706	40.09	8.988	32.58	292.81	75.26
24095-008 (Control)	1_TS0_Initial	9.893	40.09	9.312	32.44	302.06	76.16
	1_TS0_Stabilized	9.877	40.15	9.318	32.49	302.75	76.35
	1_TS2_CMLT	9.862	40.06	9.234	32.35	298.70	75.61
	1_TS4_HF10	9.701	40.07	9.131	32.24	294.39	75.74
24095-009	3_TS0_Initial	9.608	39.88	9.132	32.91	300.55	78.44

24095-009 (OSA)	3_TS0_Stabilized	9.588	39.96	9.093	33.07	300.65	78.47
	3_TS1_DH1000	9.533	39.81	9.042	32.88	297.26	78.33
	3_TS2_DH1000	9.489	39.85	8.998	32.89	295.96	78.27
24095-010 (Control)	3_TS0_Initial	9.849	40.05	9.303	32.40	301.41	76.41
	3_TS0_Stabilized	9.821	40.12	9.306	32.55	302.87	76.87
	3_TS1_DH1000	9.805	39.95	9.283	32.18	298.70	76.26
	3_TS2_DH1000	9.761	39.99	9.218	32.16	296.44	75.95

*Front-side Change from Baseline:*

Module ID	Reference	$\Delta I_{sc}$ [%]	$\Delta V_{oc}$ [%]	$\Delta I_{mp}$ [%]	$\Delta V_{mp}$ [%]	$\Delta P_{mp}$ [%]
24095-001 (OSA)	2_TS0_Initial	+0.28	-0.18	+0.11	-0.36	-0.25
	2_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	2_TS1_TC200	-0.16	-0.06	-0.23	-0.46	-0.69
	2_TS2_TC200	-0.39	+0.06	-0.32	-0.38	-0.70
	2_TS3_TC200	-1.54	-0.12	-1.82	-0.39	-2.21
24095-002 (OSA)	2_TS0_Initial	+0.22	-0.13	+0.24	-0.36	-0.12
	2_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	2_TS1_TC200	-0.22	+0.00	-0.39	-1.42	-1.81
	2_TS2_TC200	-0.35	-0.11	-0.66	-1.07	-1.73
	2_TS3_TC200	-1.52	-0.03	-1.90	-1.08	-2.97
24095-003 (Control)	2_TS0_Initial	+0.00	-0.20	-0.29	-0.18	-0.47
	2_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	2_TS1_TC200	-0.13	+0.03	-0.27	-0.16	-0.43
	2_TS2_TC200	-0.26	-0.28	-0.68	-0.73	-1.40
	2_TS3_TC200	-1.63	+0.08	-1.71	-0.22	-1.92
24095-004 (Control)	2_TS0_Initial	+0.11	-0.27	+0.12	-0.49	-0.40
	2_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	2_TS1_TC200	-0.24	+0.05	-0.28	-0.10	-0.40
	2_TS2_TC200	-0.38	-0.12	-0.50	-0.12	-0.64
	2_TS3_TC200	-1.49	+0.06	-1.65	-0.18	-1.84
24095-005 (OSA)	1_TS0_Initial	+0.29	+0.03	+0.29	-0.15	+0.13
	1_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	1_TS2_CMLT	+0.01	+0.14	-0.46	+0.20	-0.27
	1_TS4_HF10	-1.53	-0.14	-2.01	-0.38	-2.38
24095-006 (OSA)	1_TS0_Initial	+0.04	-0.15	+0.18	-0.15	+0.04
	1_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	1_TS2_CMLT	-0.41	+0.08	-0.42	+0.11	-0.30
	1_TS4_HF10	-2.14	-0.25	-2.07	-0.35	-2.39
24095-007 (Control)	1_TS0_Initial	+0.17	-0.05	-0.03	-0.03	-0.05
	1_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	1_TS2_CMLT	-0.34	-0.25	-1.59	-0.48	-2.06

	1_TS4_HF10	-1.81	-0.21	-4.01	-0.31	-4.30
24095-008 (Control)	1_TS0_Initial	+0.16	-0.15	-0.06	-0.15	-0.23
	1_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	1_TS2_CMLT	-0.15	-0.23	-0.90	-0.44	-1.34
	1_TS4_HF10	-1.79	-0.21	-2.00	-0.77	-2.76
24095-009 (OSA)	3_TS0_Initial	+0.20	-0.21	+0.43	-0.46	-0.03
	3_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	3_TS1_DH1000	-0.58	-0.38	-0.56	-0.57	-1.13
	3_TS2_DH1000	-1.04	-0.29	-1.04	-0.52	-1.56
24095-010 (Control)	3_TS0_Initial	+0.29	-0.17	-0.03	-0.46	-0.48
	3_TS0_Stabilized	+0.00	+0.00	+0.00	+0.00	+0.00
	3_TS1_DH1000	-0.17	-0.42	-0.25	-1.13	-1.38
	3_TS2_DH1000	-0.61	-0.33	-0.94	-1.19	-2.12

## MQT 11 Thermal Cycling

Module	Reference	High Temp [°C]	Low Temp [°C]	Target Cycle Count	Total Cycle Count	Open Circuit?
24095-001 (OSA)	2_TS1_TC200	85	-40	200	200	No
	2_TS2_TC200	85	-40	200	400	No
	2_TS3_TC200	85	-40	200	600	No
24095-002 (OSA)	2_TS1_TC200	85	-40	200	200	No
	2_TS2_TC200	85	-40	200	400	No
	2_TS3_TC200	85	-40	200	600	No
24095-003 (Control)	2_TS1_TC200	85	-40	200	200	No
	2_TS2_TC200	85	-40	200	400	No
	2_TS3_TC200	85	-40	200	600	No
24095-004 (Control)	2_TS1_TC200	85	-40	200	200	No
	2_TS2_TC200	85	-40	200	400	No
	2_TS3_TC200	85	-40	200	600	No
24095-005 (OSA)	1_TS3_TC50	85	-40	50	50	No
24095-006 (OSA)	1_TS3_TC50	85	-40	50	50	No
24095-007 (Control)	1_TS3_TC50	85	-40	50	50	No
24095-008 (Control)	1_TS3_TC50	85	-40	50	50	No

## MQT 12 Humidity Freeze

Module	Reference	Cycle Count	Total Cycle Count	Temp - High [°C]	Temp - Low [°C]	Humidity [% RH]
24095-005 (OSA)	1_TS4_HF10	10	10	85	-40	85
24095-006 (OSA)	1_TS4_HF10	10	10	85	-40	85
24095-007 (Control)	1_TS4_HF10	10	10	85	-40	85
24095-008 (Control)	1_TS4_HF10	10	10	85	-40	85

## MQT 13 Damp Heat

Module	Reference	Temperature [°C]	Humidity [%RH]	Target Duration Total [Hrs]	Duration [Hrs]	Total Duration [Hrs]
24095-009 (OSA)	3_TS1_DH1000	85	85	1000	1007.5	1007.5
	3_TS2_DH1000	85	85	2000	1052.3	2059.8
24095-010 (Control)	3_TS1_DH1000	85	85	1000	1007.5	1007.5
	3_TS2_DH1000	85	85	2000	1052.3	2059.8

## MQT 16 Static Mechanical Loading

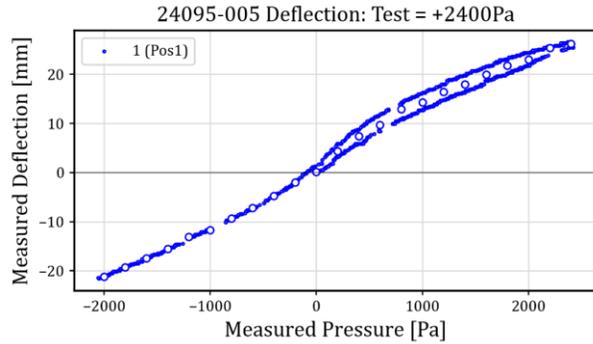
Test conditions: Modules were tested using IEC 61215-2:2021 MQT 16 Static Mechanical Loading. Testing was conducted using customer defined pressure loads and clamping. Clamps, pressures and module results are summarized in the table below. All modules went through 3 cycles of +/-2400Pa before one push at +5400Pa.

Module ID	Clamp Type	Pressure [Pa]	Coverage Ratio [%]	Pass/Fail
24095-005 (OSA)	¼ point mounting	+2400/-2400, +5400	16.9	Pass
24095-006 (OSA)	¼ point mounting	+2400/-2400, +5400	16.9	Pass
24095-007 (Control)	¼ point mounting	+2400/-2400, +5400	16.9	Pass
24095-008 (Control)	¼ point mounting	+2400/-2400, +5400	16.9	Pass

## MQT 16 Static Mechanical Load Testing: 24095-005 (OSA)

Pressure vs Deflection Plot and Data

Pressure [Pa]	Deflection [mm]	Deflection [in]
+0	+0.00	+0.00
+400	+3.11	+0.12
+800	+8.42	+0.33
+1200	+12.44	+0.49
+1600	+18.50	+0.73
+2000	+19.60	+0.77
+2400	+23.26	+0.92
+5400	+30.59	+1.20



This test was conducted using ¼ point mounting at pressures of +/-2400Pa. One final push cycle at +5400Pa was added to emulate snow load. This module passed MLT.

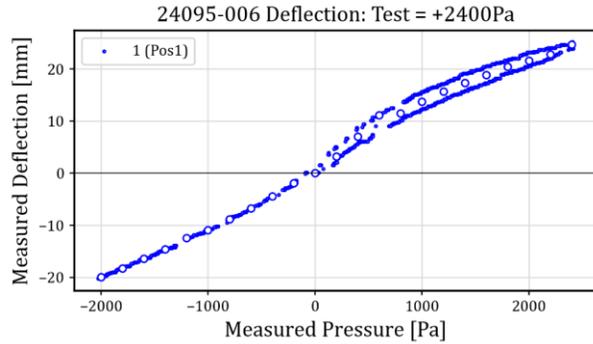
Module Deflection Images at max downward load (Top) and max upward load (Bottom)



## MQT 16 Static Mechanical Load Testing: 24095-006 (OSA)

Pressure vs Deflection Plot and Data

Pressure [Pa]	Deflection [mm]	Deflection [in]
+0	+0.00	+0.00
+400	+3.06	+0.12
+800	+7.33	+0.29
+1200	+11.72	+0.46
+1600	+15.75	+0.62
+2000	+19.60	+0.77
+2400	+23.08	+0.91
+5400	+30.22	+1.19



This test was conducted using ¼ point mounting at pressures of +/-2400Pa. One final push cycle at +5400Pa was added to emulate snow load. This module passed MLT.

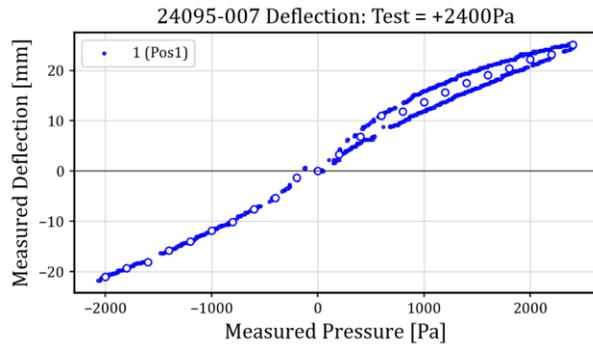
Module Deflection Images at max downward load (Top) and max upward load (Bottom)



## MQT 16 Static Mechanical Load Testing: 24095-007 (Control)

### Pressure vs Deflection Plot and Data

Pressure [Pa]	Deflection [mm]	Deflection [in]
+0	+0.00	+0.00
+400	+3.30	+0.13
+800	+8.79	+0.35
+1200	+11.72	+0.46
+1600	+15.75	+0.62
+2000	+19.44	+0.77
+2400	+25.54	+1.01
+5400	+30.77	+1.21



This test was conducted using ¼ point mounting at pressures of +/-2400Pa. One final push cycle at +5400Pa was added to emulate snow load. This module passed MLT.

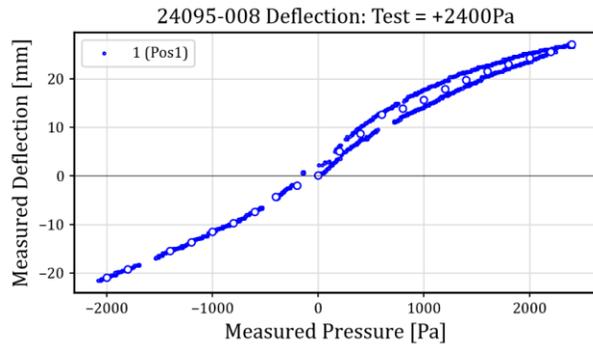
Module Deflection Images at max downward load (Top) and max upward load (Bottom)



## MQT 16 Static Mechanical Load Testing: 24095-008 (Control)

Pressure vs Deflection Plot and Data

Pressure [Pa]	Deflection [mm]	Deflection [in]
+0	+0.00	+0.00
+400	+3.48	+0.14
+800	+9.41	+0.37
+1200	+14.06	+0.55
+1600	+18.32	+0.72
+2000	+21.86	+0.86
+2400	+25.09	+0.99
+5400	+30.95	+1.22



This test was conducted using ¼ point mounting at pressures of +/-2400Pa. One final push cycle at +5400Pa was added to emulate snow load. This module passed MLT.

Module Deflection Images at max downward load (Top) and max upward load (Bottom)



## Cyclic Mechanical Loading

Modules were installed using standard 4-point mounting. Each module underwent 1000 cycles at +/-1000Pa.

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]	Coverage Ratio [%]	Pass/Fail
24095-005 (OSA)	1_TS2_CMLT	1000	1000	-1000	16.9	Pass
24095-006 (OSA)	1_TS2_CMLT	1000	1000	-1000	16.9	Pass
24095-007 (Control)	1_TS2_CMLT	1000	1000	-1000	16.9	Pass
24095-008 (Control)	1_TS2_CMLT	1000	1000	-1000	16.9	Pass

## MQT 03 Insulation

*Dielectric Withstand:*

Module ID	Reference	Voltage [V]	Duration [s]	Result
24095-001 (OSA)	2_TS0_Stabilized	6000.00	60.00	Pass
	2_TS3_TC200	6000.00	60.00	Pass
24095-002 (OSA)	2_TS0_Stabilized	6000.00	60.00	Pass
	2_TS3_TC200	6000.00	60.00	Pass
24095-003 (Control)	2_TS0_Stabilized	6000.00	60.00	Pass
	2_TS3_TC200	6000.00	60.00	Pass
24095-004 (Control)	2_TS0_Stabilized	6000.00	60.00	Pass
	2_TS3_TC200	6000.00	60.00	Pass
24095-005 (OSA)	1_TS0_Stabilized	6000.00	60.00	Pass
	1_TS2_CMLT	6000.00	60.00	Pass
	1_TS4_HF10	6000.00	60.00	Pass
24095-006 (OSA)	1_TS0_Stabilized	6000.00	60.00	Pass
	1_TS2_CMLT	6000.00	60.00	Pass
	1_TS4_HF10	6000.00	60.00	Pass
24095-007 (Control)	1_TS0_Stabilized	6000.00	60.00	Pass
	1_TS2_CMLT	6000.00	60.00	Pass
	1_TS4_HF10	6000.00	60.00	Pass
24095-008 (Control)	1_TS2_CMLT	6000.00	60.00	Pass
	1_TS4_HF10	6000.00	60.00	Pass
24095-009 (OSA)	3_TS0_Stabilized	6000.00	60.00	Pass
	3_TS2_DH1000	6000.00	60.00	Pass
24095-010 (Control)	3_TS0_Stabilized	6000.00	60.00	Pass
	3_TS2_DH1000	6000.00	60.00	Pass

*Insulation Resistance:*

Module ID	Reference	Voltage [V]	Duration [s]	Resistance: Measured/Required	Result
24095-001 (OSA)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-002 (OSA)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-003 (Control)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-004 (Control)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-005 (OSA)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	>9999	Pass
	1_TS4_HF10	1000.00	120.00	>9999	Pass
24095-006 (OSA)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	>9999	Pass
	1_TS4_HF10	1000.00	120.00	>9999	Pass
24095-007 (Control)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	>9999	Pass
	1_TS4_HF10	1000.00	120.00	>9999	Pass
24095-008 (Control)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	>9999	Pass
	1_TS4_HF10	1000.00	120.00	>9999	Pass
24095-009 (OSA)	3_TS0_Stabilized	1000.00	120.00	>9999	Pass
	3_TS2_DH1000	1000.00	120.00	>9999	Pass
24095-010 (Control)	3_TS0_Stabilized	1000.00	120.00	>9999	Pass
	3_TS2_DH1000	1000.00	120.00	>9999	Pass

## MQT 15 Wet Leakage Current

Module ID	Reference	Voltage [V]	Duration [s]	Resistance: Measured/Required	Result
24095-001 (OSA)	2_TS0_Stabilized	1000.00	120.00	413.92	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-002 (OSA)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-003 (Control)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-004 (Control)	2_TS0_Stabilized	1000.00	120.00	>9999	Pass
	2_TS3_TC200	1000.00	120.00	>9999	Pass
24095-005 (OSA)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	0.041	Fail
	1_TS4_HF10	1000.00	120.00	0.041	Fail
24095-006 (OSA)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	206.92	Pass
	1_TS4_HF10	1000.00	120.00	>9999	Pass
24095-007 (Control)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	>9999	Pass
	1_TS4_HF10	1000.00	120.00	0.041	Fail
24095-008 (Control)	1_TS0_Stabilized	1000.00	120.00	>9999	Pass
	1_TS2_CMLT	1000.00	120.00	>9999	Pass
	1_TS4_HF10	1000.00	120.00	0.00	Fail
24095-009 (OSA)	3_TS0_Stabilized	1000.00	120.00	>9999	Pass
	3_TS2_DH1000	1000.00	120.00	68.99	Pass
24095-010 (Control)	3_TS0_Stabilized	1000.00	120.00	>9999	Pass
	3_TS2_DH1000	1000.00	120.00	>9999	Pass

## Sample Information

### Labeling:

Module ID	Manufacturer	Control or OSA Cell	Serial Number
24095-001	D2 Solar	OSA	OSA-23-100-013
24095-002	D2 Solar	OSA	OSA-23-100-014
24095-003	D2 Solar	Control	OSA-23-100-004
24095-004	D2 Solar	Control	OSA-23-100-003
24095-005	D2 Solar	OSA	OSA-23-100-012
24095-006	D2 Solar	OSA	OSA-23-100-010
24095-007	D2 Solar	Control	OSA-23-100-006
24095-008	D2 Solar	Control	OSA-23-100-005
24095-009	D2 Solar	OSA	OSA-23-100-015
24095-010	D2 Solar	Control	OSA-23-100-002

### Construction Details:

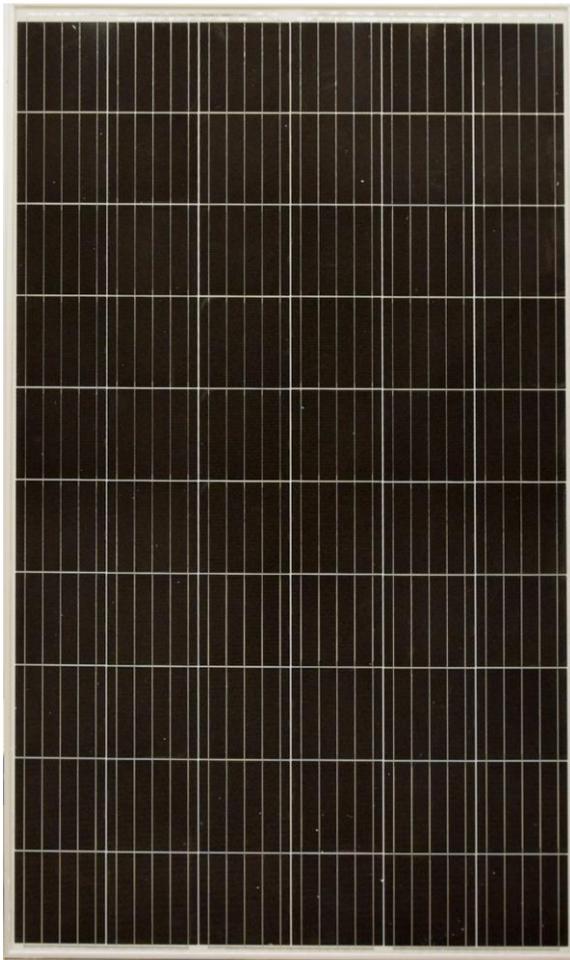
Module Type	Manufacturer	Length [m]	Width [m]	Thickness [mm]
Custom	D2 Solar	1.664	0.995	35

### Nameplate Values:

Module Type	Isc [A]	Voc [V]	Imp [A]	Vmp [V]	Pmp [W]	Max Sys Volt [V]	Fuse Rating [A]
Custom	9.43	39.97	-	-	302	1000	-

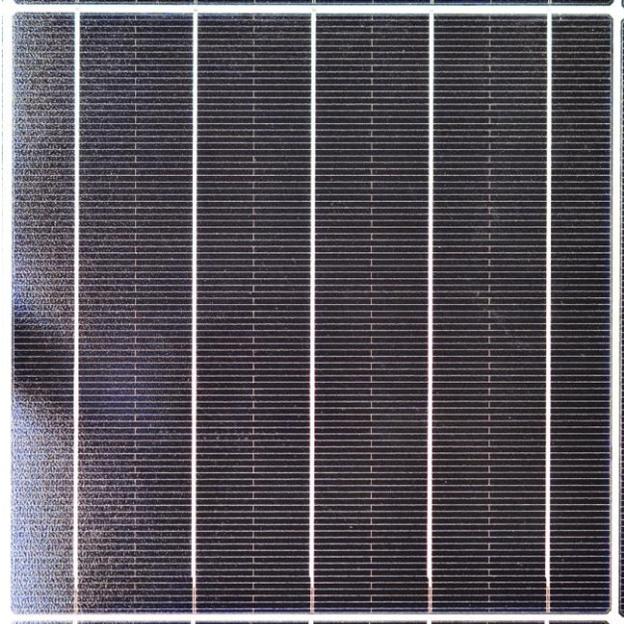
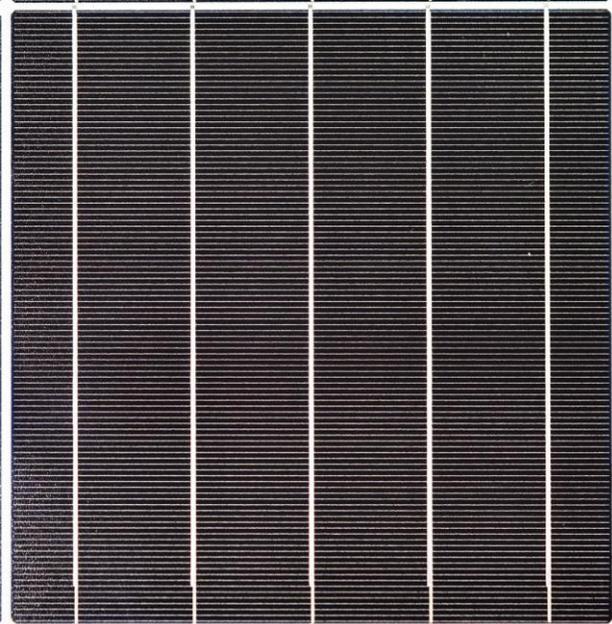
*\*Modules arrived without nameplates. Nameplate values were determined by performance data.*

*Sample Photographs:*



OSA Cell: MetZilla PERC 01  
 Model Number: MZ22-10

Control Cell:



## Procedures

The procedures are summarized in the following table.

Test Name	Standard / Procedure
Incoming Inspection	CFV
MQT 01 Visual Inspection - 2021	IEC 61215-2:2021
MQT 06.1 Performance at STC	IEC 61215-2:2021
EL Imaging 1.0x Isc	IEC 60904-13:2018
Custom Outdoor Exposure	CFV
MQT 03 Insulation - 2021	IEC 61215-2:2021
MQT 15 Wet Leakage Current - 2021	IEC 61215-2:2021
MQT 16 Static Mechanical Load - 2021	IEC 61215-2:2021
Cyclic Mechanical Loading	IEC TS 62782-2:2016
MQT 11 Thermal Cycling - 2021	IEC 61215-2:2021
MQT 12 Humidity Freeze - 2021	IEC 61215-2:2021
MQT 13 Damp Heat - 2021	IEC 61215-2:2021

### Decision Rules:

Unless otherwise specified, the decision rule used is simple acceptance as defined in ILAC G8 4.2.1. Uncertainties are not applied in the pass/fail determination.

*Estimated Measurement Uncertainty of Monofacial Silicon Modules ( $k = 2$ ):*

Technology	Isc	Voc	Imp	Vmp	Pmp
Si	±1.4%	±0.7%	±1.8%	±1.2%	±1.9%

**Procedure Notes**

For all I-V measurements the following details apply:

<b>Spectral Mismatch Factor</b>	1.0
<b>Measurement Mode</b>	Forward and reverse sweeps
<b>Measurement Duration</b>	25 ms forward, 25 ms reverse
<b>Flash Profile Type</b>	Plateau
<b>Averaging</b>	Forward and Reverse I-V measurements are averaged.

**Equipment and Calibration**

Equipment and calibration information is available upon request.

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