Flash-Test Study

Engineering Study DryWired LLC

Boviet Solar BVM6612M-365-H Module

Report No.: R3165A-1

Date: 31 July 2019

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Project name:	Flash-Test Study
Report title:	Engineering Study
Customer:	DryWired LLC
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Date of issue:	31 July 2019
Project No.:	PVEL3165

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Task and objective:

Engineering report of BVM6612M-365-H module for DryWired LLC.

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Revision	Date	Reason for Issue	Prepared by	Verified by	Approved by
1	7/31/2019	Final	Lee Malmgren	Priyanka Mogre	Ryan Desharnais

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List of abbreviations

Abbreviation	Meaning
PVEL	PVEL LLC
EL	Electroluminescence
IEC	International Electrotechnical Commission
I_{MP}	Current at maximum power
I_{SC}	Short-circuit current
P_{MAX}	Maximum power
PV	Photovoltaic
STC	Standard test conditions
V_{MP}	Voltage at maximum power
V_{OC}	Open-circuit voltage

1 Summary

DryWired LLC (DryWired) submitted four (4) BVM6612M-365-H photovoltaic (PV) modules to PVEL LLC (PVEL) for an anti-soiling coating application engineering study. Before the coating process, the modules underwent a light soak of ≥40 kWh/m^2, STC flash-testing, and electroluminescence (EL) imaging. The modules then had the anti-soiling coating applied to the four samples, two modules were coated with DryWired's Perma-Clean coating, and the other two were coated with DryWired's LumActiv coating. The modules remained outside for 24 hours while the coating cured, the liquid coating was not applied or handled by PVEL employees. The complete testing protocol can be found in Appendix A. The results of the anti-soiling coating flash-test results are presented in this report.

1.1. Manufacturer specifications

The module specifications were taken from the Boviet Solar 72 Cell Mono 355-370W BVM3312M module datasheet which was provided by the manufacturer. The datasheet can be found in Appendix B.

Boviet Solar Datasheet Specifications					
Model	**P_{MAX} [W]**	**V_{OC} [V]**	**V_{MP} [V]**	**I_{SC} [A]**	**I_{MP} [A]**
BVM6612M-365-H	365	9.94	9.39	47.60	9.39

1.2. Test data summary

The modules under test underwent the following coating applications.

Coating Specifications		
Model	**Serial Number**	**Coating Applied**
BVM6612M-365-H	MD9792E092800250	Perma-Clean
BVM6612M-365-H	MD9792E092800267	Perma-Clean
BVM6612M-365-H	MD9792E092800379	LumaActiv
BVM6612M-365-H	MD9792E092800465	LumaActiv

Average Performance Change in P_{MAX} Relative to Uncoated Measurement [%]		
Model	**Average Percent difference of Perma-Clean Coating from Uncoated Results P_{MAX} [%]**	**Average Percent difference of LumActiv Coating from Uncoated Results P_{MAX} [%]**
BVM6612M-365-H	0.11	0.01

2 Flash-Test Results

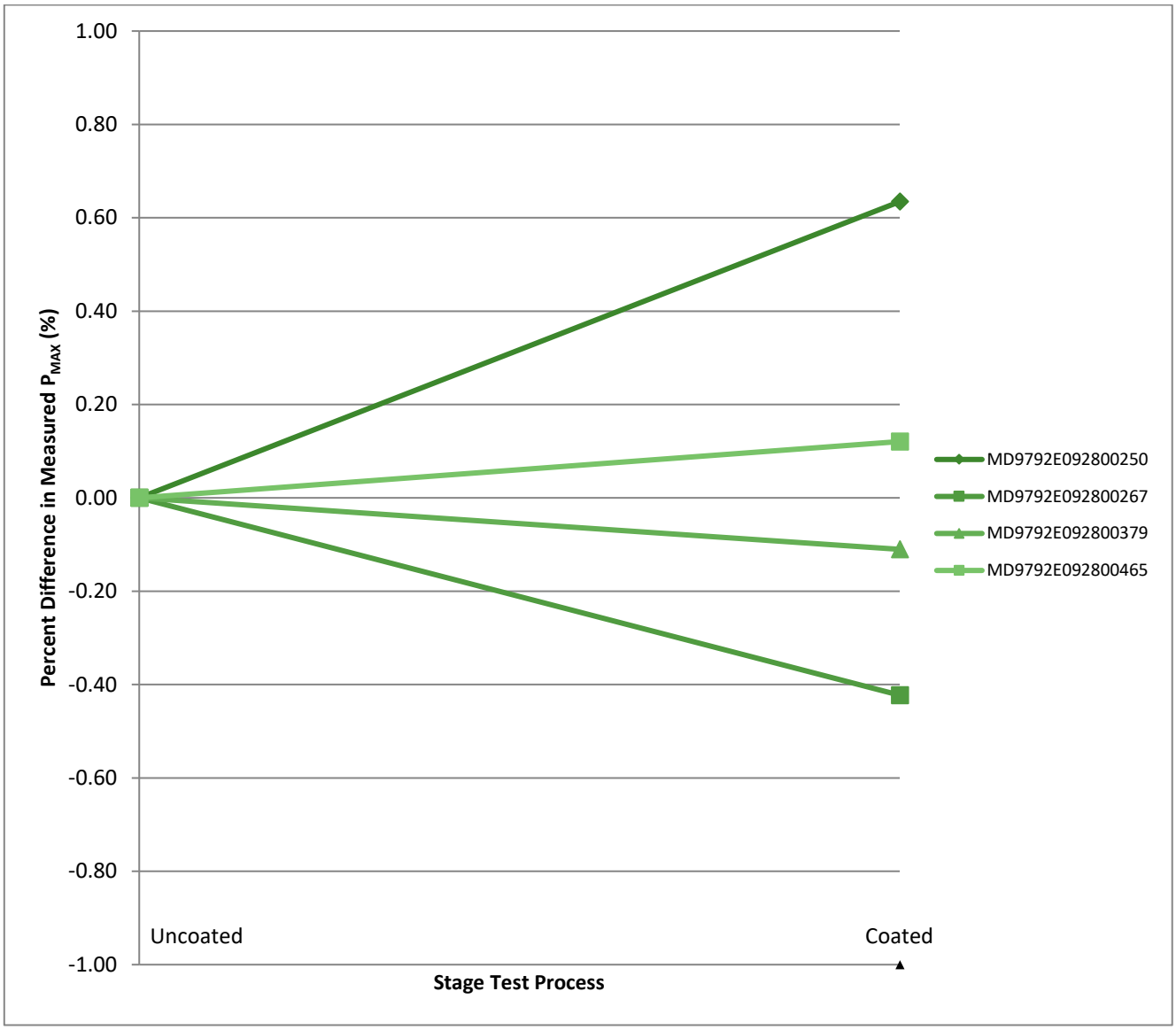


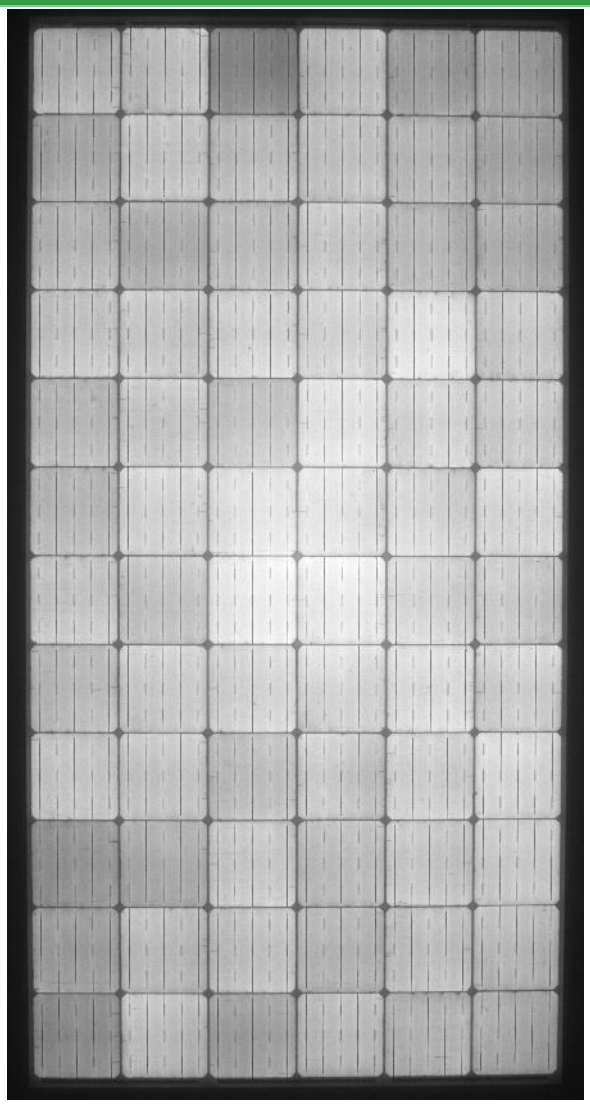
Figure 2-1 Percent deviation in measured P_{MAX} due to coating of the modules

2.1. STC performance test data

Uncoated Flash-Test Data						
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]
BVM6612M-365-H	MD9792E092800250	357.9	47.88	39.15	9.605	9.140
BVM6612M-365-H	MD9792E092800267	360.9	47.92	39.22	9.653	9.202
BVM6612M-365-H	MD9792E092800379	359.4	47.86	39.27	9.663	9.153
BVM6612M-365-H	MD9792E092800465	359.0	47.86	39.18	9.666	9.163

Coated Flash-Test Data						
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]
BVM6612M-365-H	MD9792E092800250	360.1	48.12	39.27	9.631	9.171
BVM6612M-365-H	MD9792E092800267	359.4	48.02	39.56	9.495	9.085
BVM6612M-365-H	MD9792E092800379	359.0	47.90	39.41	9.609	9.110
BVM6612M-365-H	MD9792E092800465	359.4	48.03	39.32	9.647	9.141
Percent Deviation from Uncoated Flash-Test Data						
Model	Serial Number	P_{MAX} [%]	V_{OC} [%]	V_{MP} [%]	I_{SC} [%]	I_{MP} [%]
BVM6612M-365-H	MD9792E092800250	0.63	0.51	0.30	0.26	0.34
BVM6612M-365-H	MD9792E092800267	-0.42	0.23	0.86	-1.64	-1.27
BVM6612M-365-H	MD9792E092800379	-0.11	0.10	0.36	-0.56	-0.47
BVM6612M-365-H	MD9792E092800465	0.12	0.36	0.35	-0.20	-0.23

2.2. Electroluminescence images

Model: BVM6612M-365-H Serial Number: MD9792E092800250
Uncoated


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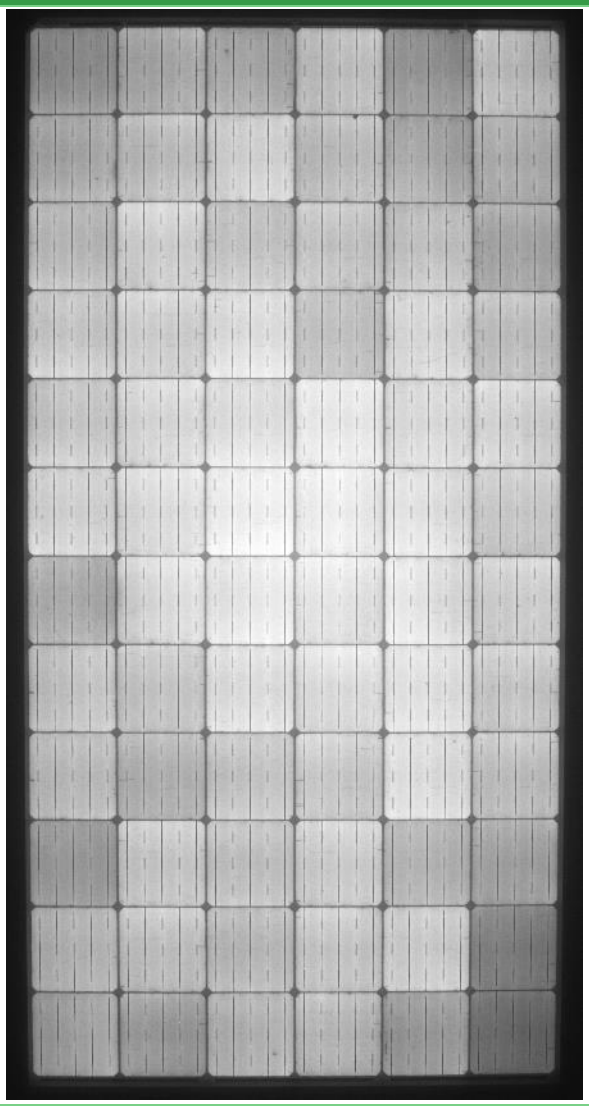

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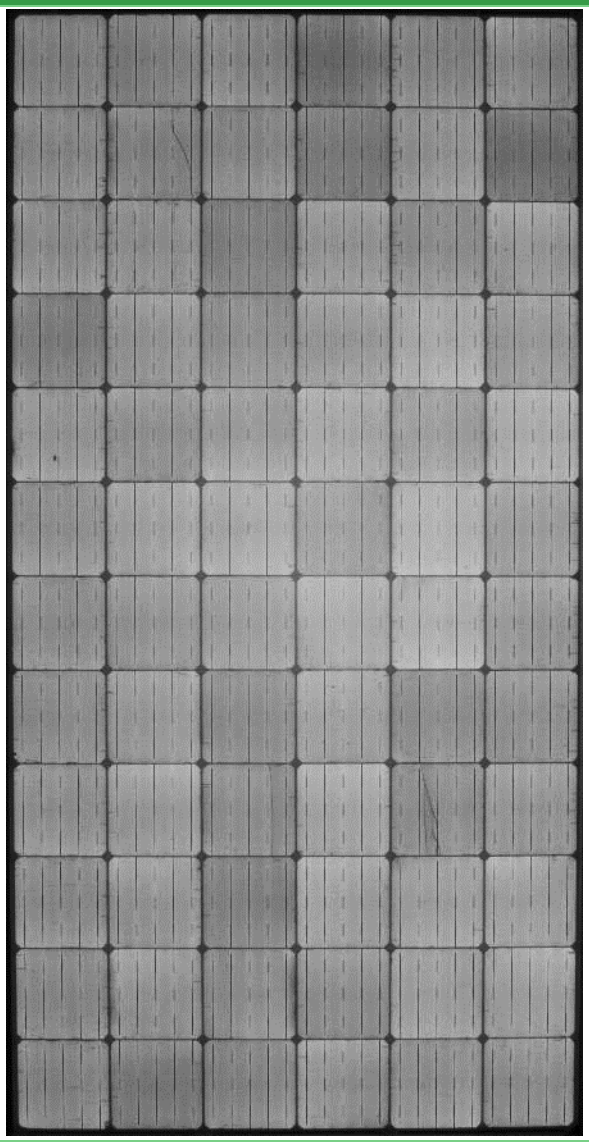

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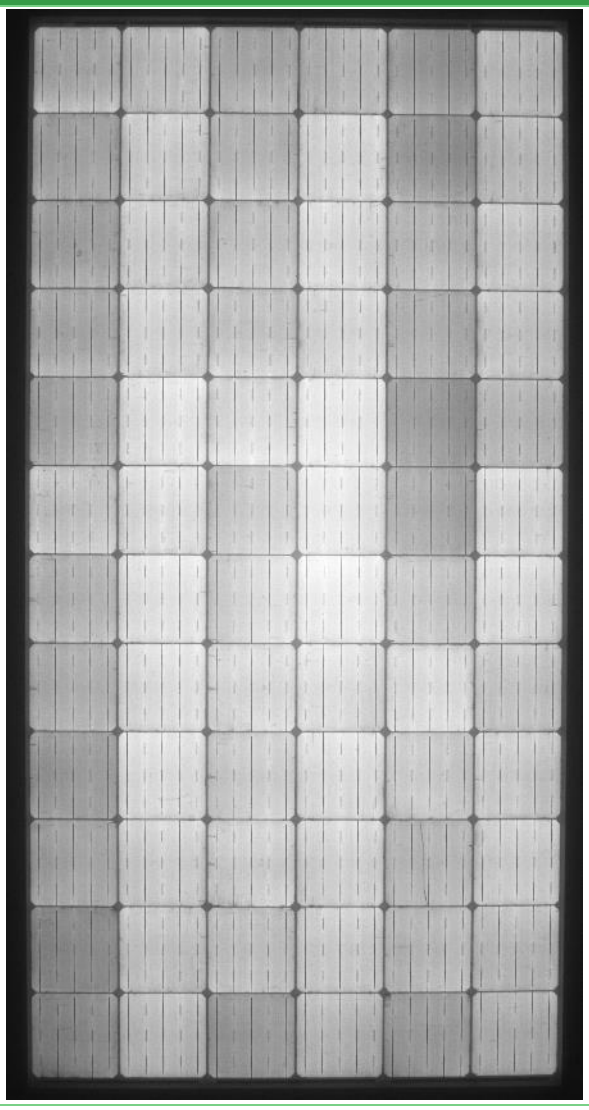
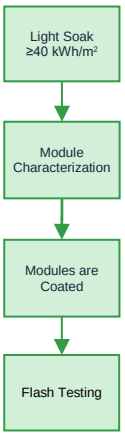
Uncoated


Appendix A – Flash-Test Coating Study

Module characterizations include one or more of the following for the test leg:

Flash-test per IEC 60904
EL image



Appendix B – Flash-test Measurement Summary

Per IEC 60904-1 Second Edition 2006-9

Pasan SunSim 3b pulsed solar simulator (flash-tester)

- Class A+A+A+
  - Non-uniformity of irradiance ≤ 1%
  - Long-term pulse instability ≤ 1%
  - Spectral irradiance distribution ≤ ± 12.5%
- All performance values are extracted from the measured I-V data
- Expanded (k = 1.96) uncertainty values at STC (assuming a spectral mismatch factor of 1 and not including module metastability behavior):
  - I_{SC}: ± 1.64%
  - V_{OC}: ± 0.79%
  - P_{MAX}: ± 2.00%
- Maximum deviation of achieved temperature/irradiance from target temperature/irradiance:
  - Temperature: ± 1°C
  - Irradiance: ± 0.5%

PVEL's Pasan SunSim 3b pulsed solar simulator was calibrated using a multi-crystalline PERC (Serial Number 823016155216600017) reference module that was calibrated by Fraunhofer-Institut für Solare Energiesysteme ISE. The next calibration due date is October 27, 2019. After calibrating the flash-tester to the reference module, the modules were flash-tested per IEC 60904-1.

Appendix C – Manufacturer Datasheet

BOVIET SOLAR USA

Advancing the Power of the Sun

72 Cell Mono 355-370W

BVM6612M

0~+5W
Power Tolerance

19.1%
Maximum Efficiency

355-370W
Power Output Range

39.06 x 77.01 Inches

Silver Frame / White Backsheet

High Quality and Reliable Modules
- Withstand up to 5400 Pa snow load and 2400 Pa wind load
- 2 EL inspections per cell/module for defect-free consistency
- Type 1 fire-rating per UL 1703 edition 3
- High salt and ammonia resistance certified by TUV Rheinland
- 0~+5 W guaranteed positive tolerance
- Rugged design for long-term durability; passed extended reliability tests

Warranty
- 12-year product warranty
- 25-year linear power output warranty

Comprehensive Certificates for Products and Management
- UL 1703, IEC 61215, IEC 61730, CEC listed, MCS and CE
- ISO 9001 for Quality Management Systems
- ISO 14001 for Environmental Management Systems
- ISO 18001 Occupational Health and Safety Systems

Listed in Bloomberg New Energy Finance's tier 1 list as of 1Q 2018

Boviet Solar USA ♦ 1740 Technology Dr., Suite 205 ♦ San Jose, CA 95110

BOVIETSOLARUSA.COM ♦ 877.253.2858 ♦ SALES@BOVIETSOLARUSA.COM

Electrical Characteristics STC				
	BVM6612M-355	BVM6612M-360	BVM6612M-365	BVM6612M-370
Maximum Power (Pmax)	355W	360W	365W	370W
Maximum Power Current (Imp)	9.20A	9.29A	9.39A	9.49A
Maximum Power Voltage (Vmp)	38.6V	38.8V	38.9V	39.0V
Short Circuit Current (Isc)	9.67A	9.83A	9.94A	10.04A
Open Circuit Voltage (Voc)	47.4V	47.5V	47.6V	47.7V
Module Efficiency	18.3%	18.5%	18.8%	19.1%
Power Tolerance	0~+5W	0~+5W	0~+5W	0~+5W
STC: AM1.5, Irradiance 1000W/m², 25°C				

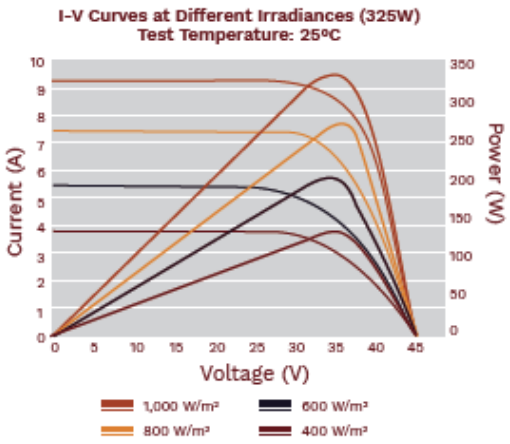
Electrical Characteristics NOCT				
	BVM6612M-355	BVM6612M-360	BVM6612M-365	BVM6612M-370
Maximum Power (Pmax)	261W	265W	269W	273W
Maximum Power Current (Imp)	7.35A	7.43A	7.50A	7.57A
Maximum Power Voltage (Vmp)	35.6V	35.7V	35.9V	36.1V
Short Circuit Current (Isc)	7.82A	7.90A	7.98A	8.05A
Open Circuit Voltage (Voc)	43.7V	43.8V	44.0V	44.3V
NOCT: AM1.5, Irradiance 800W/m², 20°C, Wind speed 1m/s				

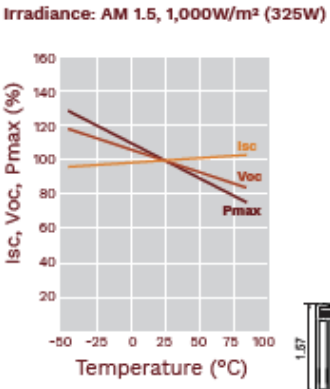
Mechanical Characteristics	
Solar Cell	Monocrystalline 6.14 x 6.14 inch, 72 (6 x 12) pcs. in series
Glass	High transparency, low iron, tempered glass 4 mm (0.16 inch)
Frame	Anodized aluminum alloy
Junction Box	IP67 rated, with 3 bypass diode
Output Cable	4 mm² (EU)/12 AWG (US), 43.30/47.244 inch
Connector	MC4 compatible
Dimension	77.01 x 39.06 x 1.57 inch
Weight	58.42 lb

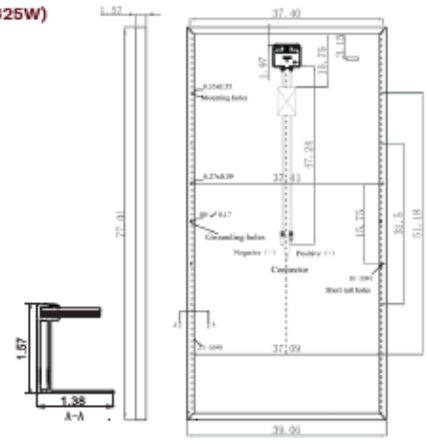
Thermal Characteristics	
Pmax Temperature Coefficient	-0.40%/K
Voc Temperature Coefficient	-0.31%/K
Isc Temperature Coefficient	+0.06%/K
NOCT	113±3.6°F

Maximum Ratings	
Operating Temperature	-40°F~185°F
Maximum Series Fuse Rating	20A
Maximum System Voltage	1000/1500V DC

Packing Information	
Pieces per pallet	26
Pallets per container (40HQ)	24
Pieces per container (40HQ)	624
Pallet weight/size	1671.1 lb/78.41 x 44.49 x 45.08 inch







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