

Product Qualification Program

Final Hail Stress Sequence Report 35 mm

JA Solar

JAM66D45-610/LB
BOM 1



Report Number: R9197E-1

Date: 15 August 2024

Kiwa PVEL

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Napa, CA 94558

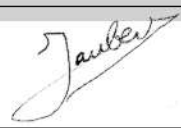
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**Report details**

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Project no.	9197	Customer Contact	Xueshan Yang
Date of issue	15 August 2024		

Approval

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Revision	Date	Reason for Issue	Preparation	Verification	Approval
1	8/15/2024	Initial Release	Charan Gurram	Jeff Cleland	Jean-Nicolas Jaubert



The test results in this report relate just to the test objects.

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1. Summary

JA Solar (JA Solar Technology Co., Ltd.) submitted JAM66D45-610/LB photovoltaic (PV) modules for accelerated stress testing and characterization under PVEL LLC's (Kiwa PVEL) Product Qualification Program (PQP). All testing in this report was completed at Kiwa PVEL's lab in Jiangsu, China. Real-world failure mechanisms outlined in Appendix C are simulated in a controlled laboratory environment, and state-of-the-art module characterization techniques are utilized to measure the performance of the modules as they progress through the protocol. The results of the PQP testing are presented in this report.

This report is part of Kiwa PVEL's PQP project 9197. Please refer to Appendices A and B for more details. BOM information can be found in report R9197A.

1. 1. Manufacturer specifications

The module specifications were taken from the datasheet provided by the customer. The datasheet can be found in Appendix F.

JAM66D45-610/LB Datasheet Specifications						
Model	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	610	48.10	39.77	16.05	15.34	79.02

1. 2. Test data summary

Average Post-stress Change in P _{MAX} Relative to Initial Measurement [%]	
Model	HSS Post-Hail
JAM66D45-610/LB	-0.97
Visual Inspection Findings ¹	
JAM66D45-610/LB	None
Wet Leakage Insulation Resistance Meets IEC 61215-1:2021 Requirements ²	
JAM66D45-610/LB	Yes
Electrical Circuitry ³	
JAM66D45-610/LB	Pass

¹ Major visual defects, if present, are defined as such by IEC 61215-1:2021.

² For reference, IEC 61215-2:2021 MQT 15 defines a passing insulation resistance for the type of module tested to be no less than 40 MΩ·m².

³ Electrical circuitry failures encompass samples exhibiting an open-circuit during or post-test, as well as bypass diode failure (as recorded in the bypass diode functionality test after the thermal cycling and mechanical stress sequences or as detected in EL pictures after other test sequences).



2. Hail Stress Sequence

As the global climate changes and PV deployment increases to a variety of locations around the world, PV modules mounted in the field may be exposed to severe hail impacts beyond what is covered by the IEC 61215 baseline hail test. These hail impacts can result in broken glass and/or cracked cells, and those cracked cells can eventually lead to power loss for hail damaged modules. Kiwa PVEL's HSS test is focused on determining a module's susceptibility to these hail impact failure modes.

The test sequence starts when test samples are struck by a 35 ± 1.8 mm / 20.7 ± 1.0 g lab-manufactured ice ball at terminal velocity 27.2 ± 1.4 m/s in 11 different locations normal to the module as indicated by IEC 61215-2:2021 MQT 17. These hail strikes deliver a nominal impact energy of 7.7 joules.

Shot No.	Module Location
1	Any corner of the module window, not more than one radius of ice-ball from the module edge.
2	Any edge of the module, not more than one radius of ice-ball from the module edge.
3, 4	Over the circuit near interconnects (i.e., cell interconnects and bus ribbons).
5, 6	Over edges of the circuit (e.g., individual cells).
7, 8	On the module window, not more than half diameter of ice ball from one of the points at which the module is mounted to the supporting structure.
9, 10	On the module window, at points farthest from the points selected above.
11	Any points which may prove especially vulnerable to hail impact like over the junction box.

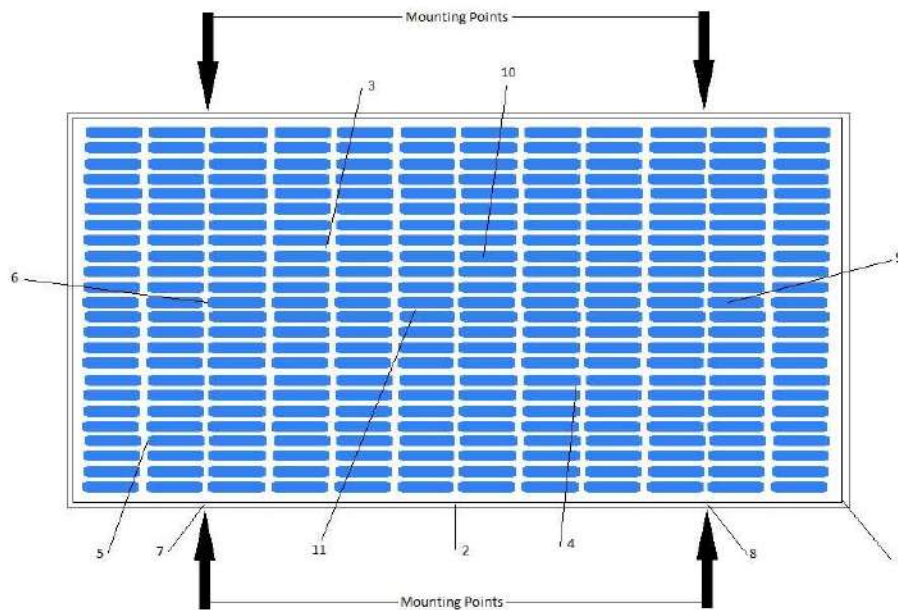


Figure 2-1: Location of 11 hail strikes.



The actual hail diameter, mass, velocity and impact locations achieved during testing were all within the allowable tolerances specified in IEC 61215-2:2021 MQT 17.

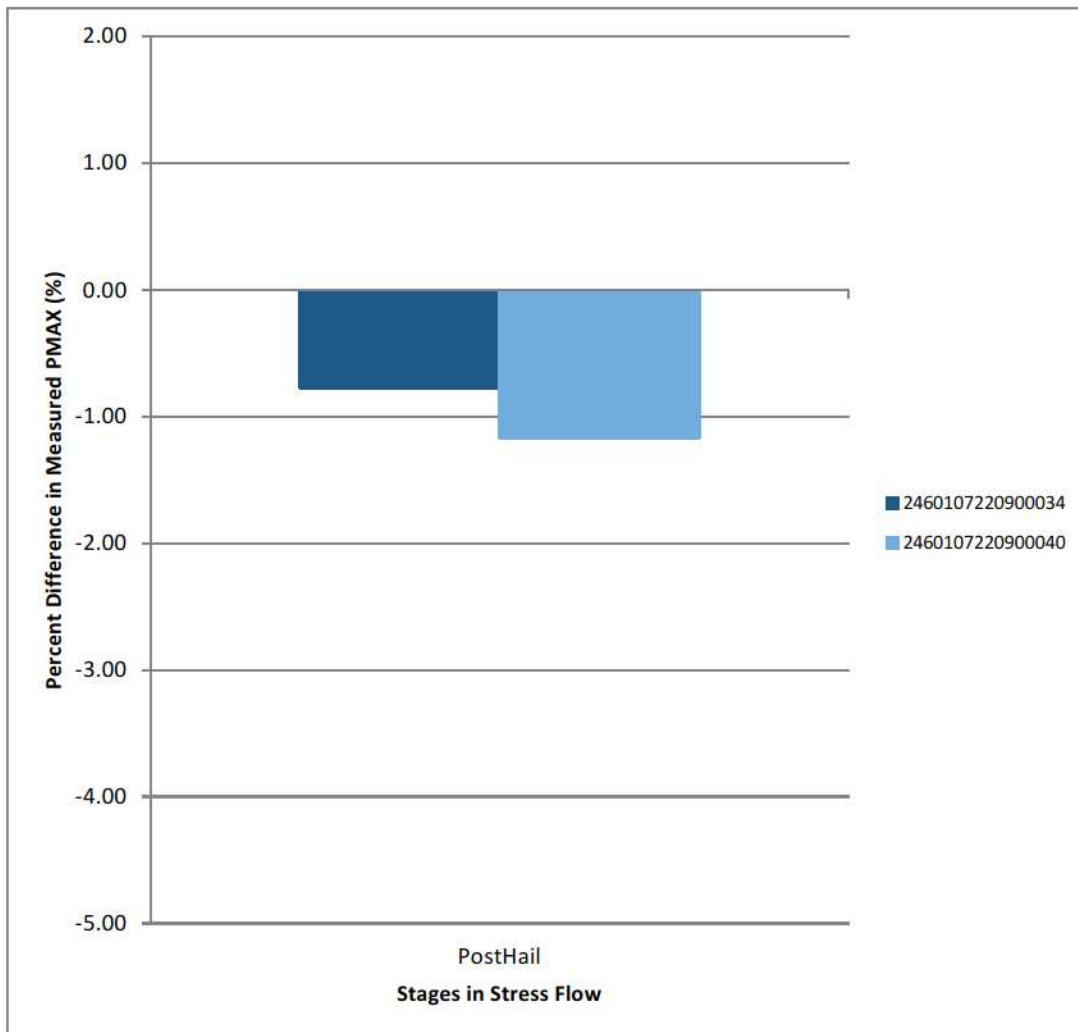


Figure 2-2 Percent deviation in measured P_{MAX} due to stress



2. 1. Front side STC performance test data - HSS

Pre-stress Test Data							
Model	Serial Number	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	2460107220900034	607.6	48.23	40.76	15.60	14.91	80.77
JAM66D45-610/LB	2460107220900040	607.6	48.28	41.04	15.59	14.80	80.70

Post-Hail Test Data							
Model	Serial Number	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	2460107220900034	602.9	48.24	40.62	15.47	14.84	80.77
JAM66D45-610/LB	2460107220900040	600.5	48.24	40.98	15.43	14.65	80.66

Percent Deviation from Pre-stress Test Data							
Model	Serial Number	P _{MAX} [%]	V _{OC} [%]	V _{MP} [%]	I _{SC} [%]	I _{MP} [%]	FF [%]
JAM66D45-610/LB	2460107220900034	-0.77	0.02	-0.34	-0.83	-0.47	0.00
JAM66D45-610/LB	2460107220900040	-1.17	-0.08	-0.15	-1.03	-1.01	-0.05



2. 2. Rear side STC performance test data - HSS

Pre-stress Test Data							
Model	Serial Number	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	2460107220900034	472.3	47.86	41.45	12.42	11.39	79.42
JAM66D45-610/LB	2460107220900040	470.6	47.87	41.58	12.37	11.32	79.49

Post-Hail Test Data							
Model	Serial Number	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	2460107220900034	468.1	47.88	41.39	12.31	11.31	79.42
JAM66D45-610/LB	2460107220900040	465.3	47.83	41.42	12.28	11.23	79.19

Percent Deviation from Pre-stress Test Data							
Model	Serial Number	P _{MAX} [%]	V _{OC} [%]	V _{MP} [%]	I _{SC} [%]	I _{MP} [%]	FF [%]
JAM66D45-610/LB	2460107220900034	-0.90	0.04	-0.14	-0.89	-0.70	0.00
JAM66D45-610/LB	2460107220900040	-1.13	-0.08	-0.38	-0.73	-0.80	-0.37



2. 3. Front side 200 W/m² performance test data - HSS

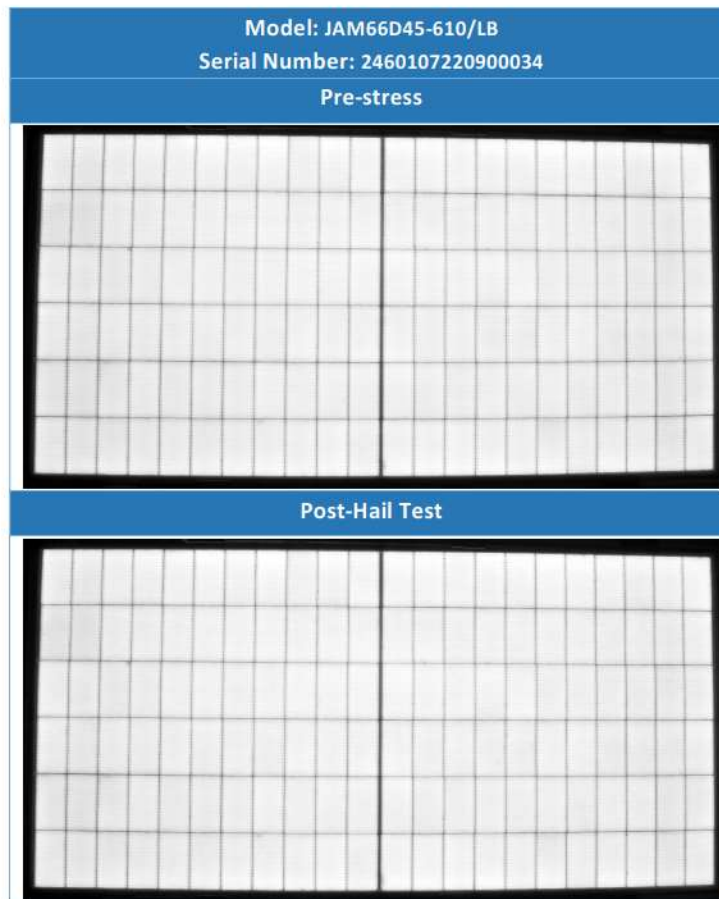
Pre-stress Test Data							
Model	Serial Number	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	2460107220900034	115.9	45.59	39.58	3.07	2.93	82.86
JAM66D45-610/LB	2460107220900040	116.0	45.53	39.76	3.09	2.92	82.52

Post-Hail Test Data							
Model	Serial Number	P _{MAX} [W]	V _{OC} [V]	V _{MP} [V]	I _{SC} [A]	I _{MP} [A]	FF [%]
JAM66D45-610/LB	2460107220900034	115.9	45.60	39.60	3.07	2.93	82.88
JAM66D45-610/LB	2460107220900040	115.4	45.54	39.72	3.07	2.91	82.67

Percent Deviation from Pre-stress Test Data							
Model	Serial Number	P _{MAX} [%]	V _{OC} [%]	V _{MP} [%]	I _{SC} [%]	I _{MP} [%]	FF [%]
JAM66D45-610/LB	2460107220900034	0.03	0.02	0.05	0.00	0.00	0.03
JAM66D45-610/LB	2460107220900040	-0.51	0.02	-0.10	-0.65	-0.34	0.18



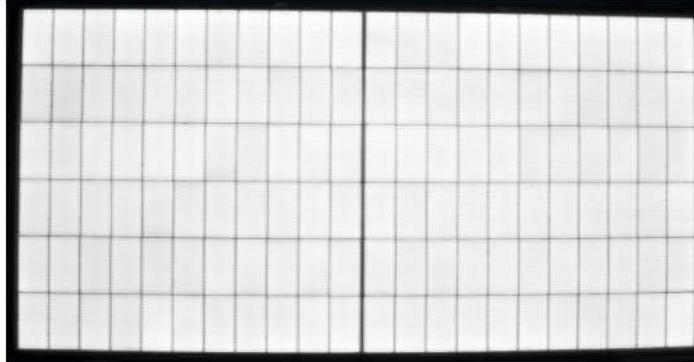
2. 4. 1.0 * I_{SC} Electroluminescence images – HSS



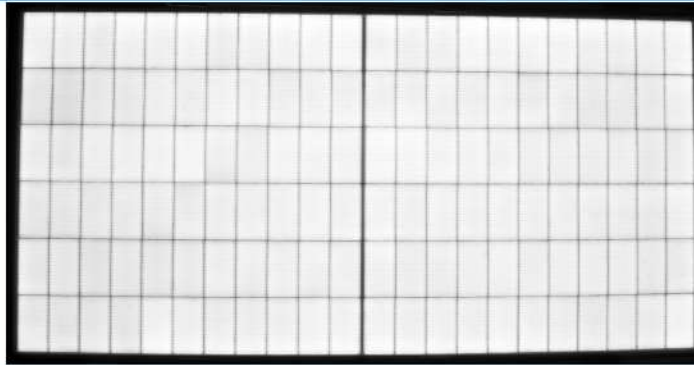


Model: JAM66D45-610/LB
Serial Number: 2460107220900040

Pre-stress

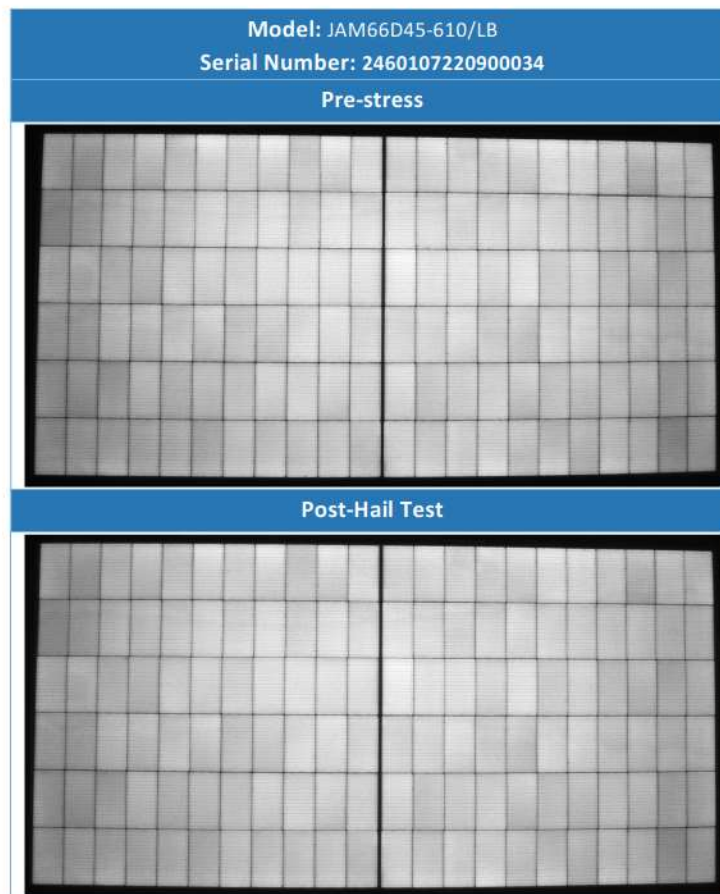


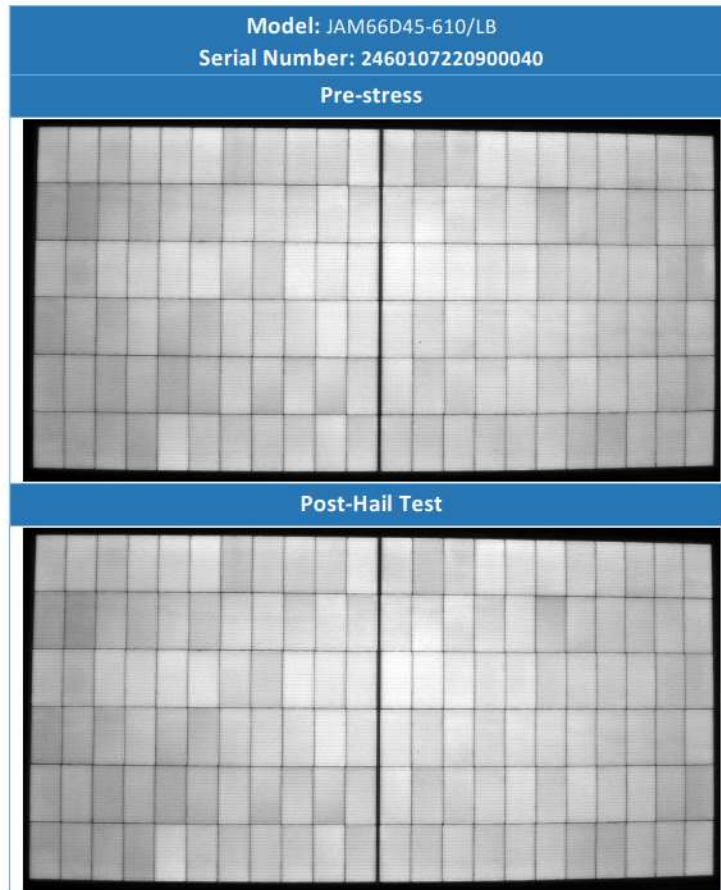
Post-Hail Test





2. 5. 0.1 * I_{SC} Electroluminescence images - HSS







2. 6. Visual inspection notes – HSS

Pre-stress Inspection Notes				
Model	Serial Number	Notes	Defect Category	Photo
JAM66D45-610/LB	2460107220900034	Not Applicable	None	Not Applicable
JAM66D45-610/LB	2460107220900040	Not Applicable	None	Not Applicable

Post-Hail Test Inspection Notes				
Model	Serial Number	Notes	Defect Category	Photo
JAM66D45-610/LB	2460107220900034	Not Applicable	None	Not Applicable
JAM66D45-610/LB	2460107220900040	Not Applicable	None	Not Applicable



2. 7. Wet leakage current test data – HSS

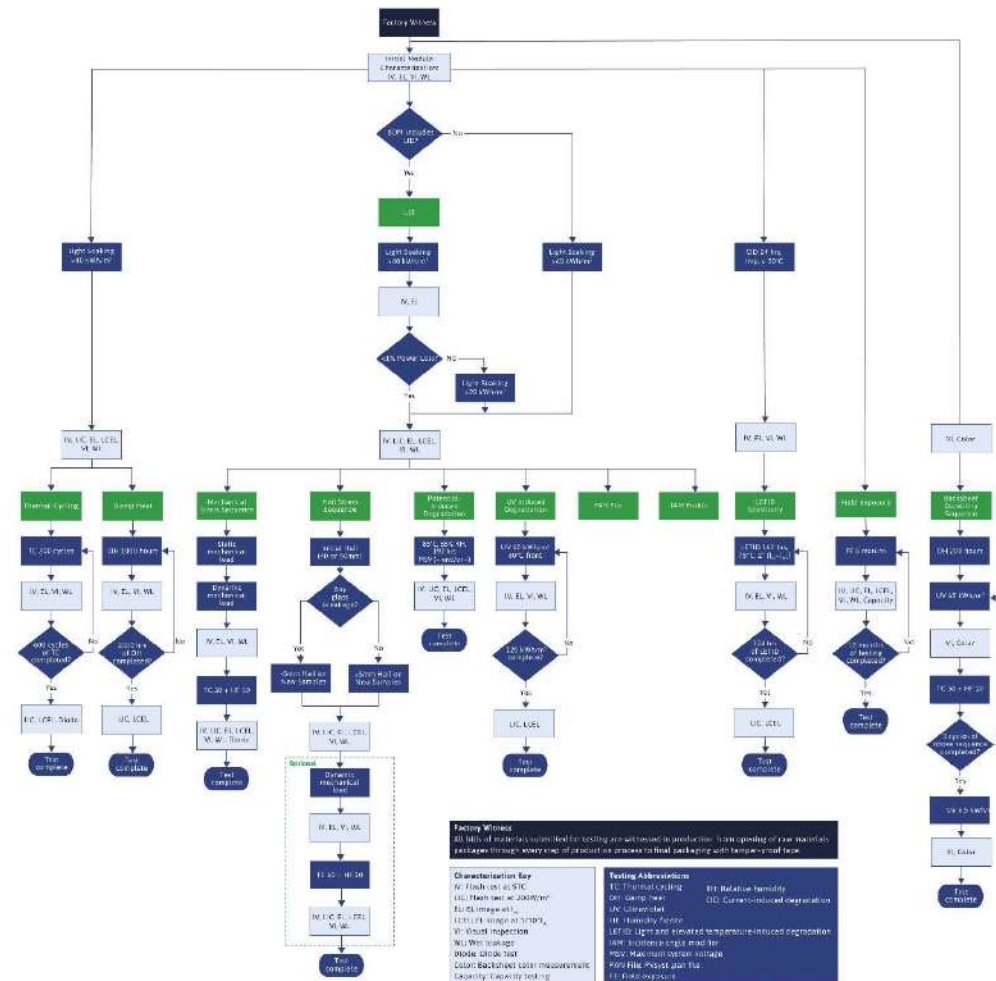
Pre-stress Test Data			
Model	Serial Number	Insulation Resistance [MΩ·m ²]	Within IEC 61215's Requirement
JAM66D45-610/LB	2460107220900034	21114	Yes
JAM66D45-610/LB	2460107220900040	20871	Yes

Post-Hail Test Data			
Model	Serial Number	Insulation Resistance [MΩ·m ²]	Within IEC 61215's Requirement
JAM66D45-610/LB	2460107220900034	18684	Yes
JAM66D45-610/LB	2460107220900040	17091	Yes



Exhibit A – BOM Details

PI Berlin witnessed the production of the modules tested in this report and verified the BOM components. BOM information can be found in Kiwa PVEL Report R9197A.





Appendix B – List of Reports

The following is a list of all reports issued over the duration of an entire module PQP.

- Witness Report
- Intake Report
- Light-induced Degradation Report
- Hail Stress Sequence Report
- Interim Reliability Report
- Final Reliability Report
- Interim Backsheet Durability Report (not required for glass//glass modules)
- Final Backsheet Durability Report (not required for glass//glass modules)
- Optional: PAN File Parameter Measurement Report
- Optional: Incidence Angle Modifier Report
- Optional: Interim Field Exposure Report
- Optional: Final Field Exposure Report



Appendix C – Typical PV Module Failure Mechanisms

	Light Induced Degradation	Light and Elevated Temperature Induced Degradation	Thermal Cycling	Damp Heat	Backsheet Durability Sequence	Mechanical Stress Sequence	Hail Stress Sequence	Potential-Induced Degradation (PID)
Corrosion of cell metallization				✓		✓	✓	
Junction box failure (solder joints, arcing, etc.)			✓			✓	✓	
Glass fracture						✓	✓	
Bypass diode failure (short or open)			✓	✓		✓	✓	
Cracked cells			✓			✓	✓	
Solder joint degradation			✓			✓	✓	
Delamination				✓	✓			
Junction box detach				✓				
Connector embrittlement (moisture ingress)			✓	✓	✓			
Frame tape or frame adhesive failure						✓		
Frame fatigue						✓		
Optical degradation of encapsulant and backsheet					✓			
Light-Induced Degradation (LID)	✓							
Light and Elevated Temperature Induced Degradation (LETID)		✓						
Outgassing of in-laminate materials (Chemical incompatibilities)			✓	✓	✓	✓	✓	
Backsheet embrittlement leading to cracks			✓	✓		✓	✓	
Busbar sharp edges, solder peaks, cutting through backsheet			✓					
Electrochemical corrosion of busbars or cell metallization								✓
Ion migration / Polarization / Potential-Induced Degradation (PID)								✓
Discoloration of frame, junction box, or polymeric materials				✓	✓	✓	✓	
Backsheet stack layer delamination				✓		✓	✓	
Hail damage							✓	



Appendix D – Flash-Test Measurement Summary

HALM CetisPV-Moduletest3 pulsed solar simulator (flash-tester)

- Class A+A+A+
 - Non-uniformity of irradiance $\leq 1\%$
 - Long-term pulse instability $\leq 1\%$
 - Spectral irradiance distribution $\leq \pm 12.5\%$
- All performance values are extracted from the measured I-V data
- Expanded ($k = 2$) uncertainty values at STC (assuming a spectral mismatch factor of 1 and not including module metastability behavior):
 - I_{SC} : $\pm 2.0\%$
 - V_{OC} : $\pm 0.8\%$
 - P_{MAX} : $\pm 2.1\%$
- Maximum deviation of achieved temperature/irradiance from target temperature/irradiance:
 - Temperature: $\pm 1^\circ\text{C}$
 - Irradiance: $\pm 0.5\%$

PI's HALM CetisPV-Moduletest3 pulsed solar simulator was calibrated using the reference module listed below.

Tested Device Technology	Reference Module Identifier	Reference Module Technology	Calibration Laboratory	Next Calibration Due Date
p-type crystalline-Si PERC	750007740237001726	p-type crystalline-Si PERC	NIM	May 5, 2025

After calibrating the flash-tester to the reference module, the modules were flash-tested following the guidance of IEC 60904-1:2020.



Appendix E – List of Abbreviations

Abbreviation	Meaning
BOM	Bill of Material
BSF	Back Surface Field
CdTe	Cadmium Telluride
Kiwa PVEL	Kiwa PVEL LLC
EL	Electroluminescence
HJT	Heterojunction
IEC	International Electrotechnical Commission
IBC	Interdigitated Back Contact
I_{MP}	Current at maximum power
I_{SC}	Short-circuit current
PERC	Passivated Emitter and Rear Contact
P_{MAX}	Maximum power
PQP	Product Qualification Program
PV	Photovoltaic
STC	Standard test conditions
V_{MP}	Voltage at maximum power
V_{OC}	Open-circuit voltage



Appendix F – Manufacturer Datasheet

The manufacturer's datasheet(s) are included on the following pages.

Harvest the Sunshine

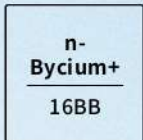
620W



JA SOLAR

JAM66D45 LB n-type Double Glass Bifacial Modules

Premium Cells



MBB Half-Cell
Technology

26%



Cell Conversion
Efficiency

Premium Modules



Higher power
generation better LCOE



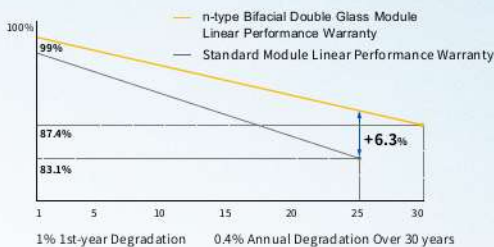
LID n-type with very
Lower LID



Better Temperature
Coefficient



Better low irradiance
response



12-year product
warranty



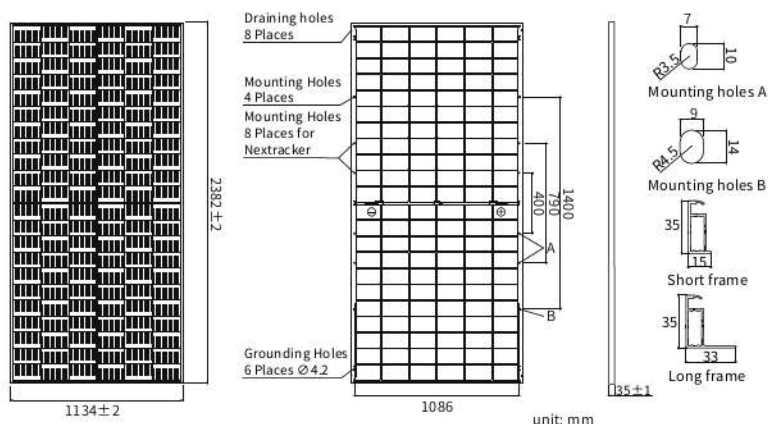
30-year linear power
output warranty

Comprehensive Certificates

- IEC 61215, IEC 61730, UL 61215, UL 61730
- ISO 9001: 2015 Quality management systems
- ISO 14001: 2015 Environmental management systems
- ISO 45001: 2018 Occupational health and safety management systems
- IEC 62941: 2019 Terrestrial photovoltaic (PV) modules - Quality system for PV module manufacturing



DEEP BLUE 4.0 Pro



MECHANICAL PARAMETERS

Cell	Mono
Weight	33.2kg
Dimensions	2382±2mm×1134±2mm×35±1mm
Cable Cross Section Size	4mm²(IEC), 12 AWG(UL)
No. of cells	132(6×22)
Junction Box	IP68, 3diodes
Connector	QC 4.10-351
Cable Length (including Connector)	400mm(+)/400mm(-)
Front Glass/Back Glass	2.0mm/2.0mm
Packaging Configuration	31pcs/Pallet, 620pcs/40HQ Container

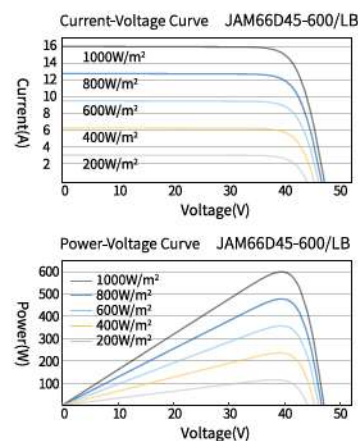
Remark: customized frame color and cable length available upon request

ELECTRICAL PARAMETERS AT STC

	JAM66D45	JAM66D45	JAM66D45	JAM66D45	JAM66D45	JAM66D45
TYPE	595/LB	600/LB	605/LB	610/LB	615/LB	620/LB
Rated Maximum Power(Pmax) [W]	595	600	605	610	615	620
Open Circuit Voltage (Voc) M	47.50	47.70	47.90	48.10	48.30	48.50
Maximum Power Voltage(Vmp) [V]	39.27	39.44	39.60	39.77	39.96	40.21
Short Circuit Current(Isc) [A]	15.90	15.95	16.00	16.05	16.10	16.13
Maximum Power Current(Imp) [A]	15.15	15.21	15.28	15.34	15.39	15.42
Module Efficiency [%]	22.0	22.2	22.4	22.6	22.8	23.0
Power Tolerance	0~+3%					
Temperature Coefficient of Isc(α_{Isc})	+0.045%/°C					
Temperature Coefficient of Voc (β_{Voc})	-0.250%/°C					
Temperature Coefficient of Pmax(γ_{Pmp})	-0.290%/°C					
STC	Irradiance 1000W/m ² , cell temperature 25°C, AM1.5G					

Remark: Electrical data in this catalog do not refer to a single module and they are not part of the offer. They only serve for comparison among different module types.

CHARACTERISTICS



ELECTRICAL CHARACTERISTICS WITH 10% SOLAR IRRADIATION RATIO

	JAM66D45	JAM66D45	JAM66D45	JAM66D45	JAM66D45	JAM66D45
TYPE	595/LB	600/LB	605/LB	610/LB	615/LB	620/LB
Rated Max Power(Pmax) [W]	643	648	653	659	664	670
Open Circuit Voltage(Voc) [V]	47.50	47.70	47.90	48.10	48.30	48.50
Max Power Voltage(Vmp) [V]	39.27	39.44	39.60	39.77	39.96	40.21
Short Circuit Current(Isc) [A]	17.17	17.23	17.28	17.33	17.39	17.42
Max Power Current(Imp) [A]	16.36	16.43	16.50	16.56	16.62	16.65
Irradiation Ratio (rear/front)	10%					

* For Nextracker installations, maximum static load please take compatibility approve letter between JA Solar and Nextracker for reference.

** Bifaciality= $P_{\text{max, rear}}/\text{Rated } P_{\text{max, front}}$

OPERATING CONDITIONS

Maximum System Voltage	1500V DC
Operating Temperature	-40°C~+85°C
Maximum Series Fuse Rating	35A
Maximum Static Load, Front*	5400Pa(112 lb/ft²)
Maximum Static Load, Back*	2400Pa(50 lb/ft²)
NOCT	45±2°C
Bifaciality**	80%±5%
Safety Class	Class II
Fire Performance	UL Type 29/Class C