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SOLARTECHNIK

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Test Report No. C1916

Solar thermal collector (liquid heating)
PVT collector
Standards: ISO 9806:2017, EN 12975:2022

Collector model: **Black Diamond BSM-425**

Test ordered by:

PVT Solar AG
Dorfstrasse 45
CH 6036 Perlen
Switzerland

Manufacturer:

PVT Solar AG
Dorfstrasse 45
CH 6036 Perlen
Switzerland

Remarks:
The content of this test report shall not be modified.
The test methods applied fulfil the requirements of ISO 9806:2017.
The rating of the test results fulfils the requirements of EN 12975:2022.
The results given in this report relate to the tested sample(s) only.
This report is following the requirements of ISO 9806:2017, EN 12975:2022.
This test report fulfils the requirements of ISO 17025.

Rapperswil, 08. February 2024

Dr. Andreas Bohren
Head of SPF Testing

The validity and authenticity of this report can be checked anytime
www.spf.ch/i-Report Name: iC1916.pdf Password: PA48kv7g

1 Summary and main results

Clause in ISO 9806:2017 / Test		Date	Results/Observations	
--	Random sampling	29.11.2022	- - -	-
--	Delivery of test sample(s)	30.11.2022	ok	-
--	Initial visual inspection	30.11.2022	ok	0
6	Maximum operating pressure	09.05.2023	6 bar	0
9	Standard stagnation temperature	24.01.2023 – 02.05.2023	70°C	0
10	Exposure or half-exposure	See clause 2.1	ok	0
11	External thermal shock 1 / 2	NR	- - -	0
12	Internal thermal shock 1 / 2	19.04.2023 / 19.04.2023	Climate class A	0
13	Rain penetration	09.05.2023	ok	0
14	Freeze resistance	- - -	NR	-
15	Mechanical load (positive)	22.06.2023	3000 Pa	0
15	Mechanical load (negative)	22.06.2023	3000 Pa	0
16	Impact Resistance	10.05.2023	35 mm	0
27	Pressure drop	12.04.2023	ok	-
19	Thermal performance	24.01.2023 – 02.05.2023	- - -	0
	A_G Collector gross area		1.95 m^2	-
	$\eta_{0,hem}$ Collector efficiency based on hemispherical irradiance		0.512	-
	$\eta_{0,b}$ Peak collector efficiency based on beam irradiance		0.517	-
	K_d Incidence angle modifier for diffuse solar radiation		0.94	-
	a_1 Heat loss coefficient		21.30 $Wm^{-2}K^{-1}$	-
	a_2 Temperature dependence of the heat loss coefficient		0.0083 $Wm^{-2}K^{-2}$	-
	a_3 Wind speed dependence of the heat loss coefficient		2.649 $Wsm^{-3}K^{-1}$	-
	a_4 Sky temperature dependence of the heat loss coefficient		0.49	-
	a_5 Effective thermal capacity incl. fluid (C/A_G)		14'642 $Wsm^{-2}K^{-1}$	-
	a_6 Wind speed dependence of the zero-loss efficiency		0.000 sm^{-1}	-
	a_7 Wind speed dependence of IR radiation exchange		0.00 sm^{-1}	-
	a_8 Radiation losses		0.000 $Wm^{-2}K^{-4}$	-
	Average flowrate during the measurement		140 lh^{-1}	-

26	Incidence angle	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	
26	$K_b(\theta_T,0)$	0.00	1.00	1.00	1.00	0.99	0.98	0.93	0.83	0.58	0.00	-
26	$K_b(0,\theta_L)$	0.00	1.00	1.00	1.00	0.99	0.98	0.93	0.83	0.58	0.00	-

25	Time constant	09.02.2023	241 s	-
17	Final inspection	10.05.2023	ok	0

Table 1: Summary of results

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2 Introduction

2.1 Remarks on the test sequence

Testing of PVT collector according to ISO 9806:2017 and the Solar Keymark Scheme Rules R6 Edition 2022-06-02 and Annex P5.1, R2 Edition 2021-01-18. All the PV related tests are performed by SUPSI (SUPSI test report 23-042-A-REP2-rev1) to confirm compliance with the relevant PV standards. Considering clause 11 of Annex P5.1, the outdoor exposure test of the ISO 9806:2017 was replaced by the damp heat (MST 53/MQT 13) and the thermal cycling test (MQT 11).

2.2 Test standards

The collector was tested according to the standards
- ISO 9806:2017
- EN 12975:2022

Complementary information which is not required by these standards is specifically marked.

2.3 Manufacturer information

All manufacturer information in this report was plausibility checked by the test laboratory and is not specifically marked anymore.

2.4 Specific abbreviations and formats used in the report

NR	Not required, not relevant
NA	Not applicable
NS	Not specified
NT	Not tested
--	No result as test was not performed
0	No problem (description see 0)
1	Minor problem (description see 0)
2	Major failure (description see 0)

Date and time is always indicated in the format (if applicable) DD.MM.YYYY HH:MM:SS

Indications about tilt angle and collector inclination are always measured from horizontal.
Length always denotes the distance in vertical (south-north) direction as tested
Width always denotes the distance in horizontal (east-west) direction as tested.

Some of the thermal performance parameters may be set to zero as described in the ISO 9806:2017: In this case a result of 0 is indicated with the number of trailing zeros as required for this parameter.

The term “water-glycol” is used for a 33.3 Vol-% ethylene-glycol mixture with water.

2.5 Test location, instrumentation and test devices

All tests are performed in the premises and on the testing field of the SPF Institute for Solar Technology of the Eastern Switzerland University of Applied Sciences (OST) in CH-8640 Rapperswil

The instrument types, specifications, serial numbers and calibration status of the instruments and test devices which were used to make the measurements and tests for this test report are filed in an internal database at the test laboratory. Upon request all this information can be made available as required by the ISO 17025.

3 Collector descriptions

3.1 Sample identification

Name of manufacturer	PVT Solar AG
Collector name	Black Diamond BSM-425
Additional brand names (if applicable)	None
Collector type	PVT collector
Serial No of test sample(s)	BSM220627106620AK / BSM220627106661AK
Serial product	Yes
Photograph(s) of the collector(s)	See Figure 6
Remarks	None
Specific comments on the collector design:	None

3.2 Collector mounting possibilities

On tilted roof	Yes
Horizontal installation	No
In tilted roof	No
Façade	No
On Stand (ground / flat-roof)	Yes
Schematic diagram of collector mounting	See Figure 9

3.3 Protection mechanisms and integrated electrical components

Description and technical details of integrated electrical components	NA
Self-protecting collector as defined in ISO 9806:2017 Clause 5.2.2	No
Freeze resistant collector as defined in ISO 9806:2017 Clause 14.2	No
Freeze resistant heat pipes as defined in ISO 9806:2017 Clause 14.3	No
Description of protection mechanism(s)	NA

3.4 Operational range

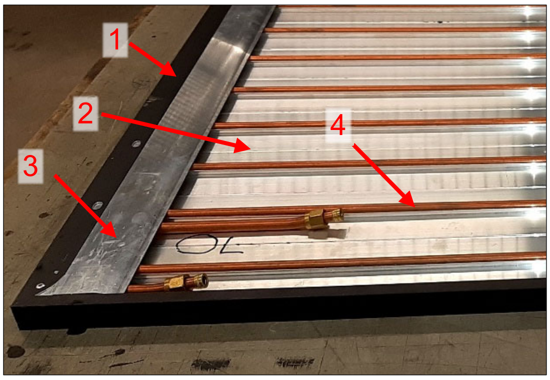
Minimum / Maximum operation temperature	-40 / 85 °C
Maximum operation pressure (at maximum temperature of operation)	$4x10^5$ Pa (4 bar)
Minimum / Maximum installation inclination	6° / 90°
Recommended heat transfer fluid(s)	water-glycol
Additional remarks concerning the heat transfer fluid(s)	None
Flow rate minimum / recommended / maximum	50 / 150 / 200 lh^{-1}
Other limitations	None

3.5 Dimensions and general information

Gross length (length from bottom to top, orientation as tested)	1722 mm
Gross width (width from left to right, orientation as tested)	1134 mm
Gross height	30 mm
Gross area, A_G (as defined in ISO 9488)	1.95 m^2
Aperture area, A_{Ap} (as defined in ISO 9488)	1.89 m^2
Absorber area, A_{Abs} (as defined in ISO 9488)	1.89 m^2
Weight empty	35 kg
Fluid content (with connecting tubes)	2.16 l

3.6 Specifications on elements

3.6.1 Collector cross section



Legend
1 Frame / PV Module
2 Absorber
3 Absorber fixing profile
4 Hydraulic system

Figure 1: Collector cross section

3.6.2 Frame, enclosure, casing

Legend No	1
Construction type	Casing (PV Module)
Enclosure material	Aluminium extruded profiles
Thickness	1.3 mm
Joining method	Glued corners with corner joints

3.6.3 PV-Module

Legend No	1
Type	BSM425G12-54HPH
P_{max}	425 W
Temperature Coefficient P_{max}	-0.35%/°C
Datasheet	see Annex C

3.6.4 Thermal absorber (backside of PVT)

Legend No	2
Material	Aluminium
Number of absorber elements (fins, tubes, etc.)	18
Distance between absorber elements	93 mm
Absorber element length / width	93 / 984 mm
Absorber total length / width	1581 / 984 mm
Absorber thickness	1.0 - 1.4 mm
Absorber coating	None
Absorber coating trade name	None
Solar absorptance α / hemispherical emittance ε	--
Bond between riser and fin/plate	Glued and clamped

3.6.5 Hydraulic system

Legend No	4
Flow pattern	Meander, See Figure 8
Number of risers	1
Riser material	Copper
Riser length	22360 mm

Riser diameter outer / inner	8.0 / 7.0 mm
Distance between risers	93 mm
Manifold material	--
Manifold length	-- mm
Manifold diameter outer / inner	-- mm
Collector hydraulic connector type/size	Corrugated tube 12 mm

3.6.6 Transparent cover(s)

Legend No	Not visible
Material	Tempered glass
Number of serial glazing	1
Thickness	4.6 mm
Diameter (for tube collectors only) outer / inner	-- / -- mm
Solar transmittance	unknown
Glazing surface characteristics	structured

3.6.7 Other elements

Absorber fixation (Legend No. 1)	Aluminium
Gluing between absorber und PV module (not visible)	EPDM

3.7 Technical documentation and safety requirements (EN 12975:2022)

3.7.1 Labelling

The collector carries a visible and durable label.	Yes

3.7.1.1 Mandatory information on the label

Name of manufacturer	Yes
Model	Yes
Serial number	Yes
Year of production (can be included in the serial number)	Yes
Peak power	Yes
Maximum operating pressure	Yes
Weight of empty collector	Yes
Volume of heat transfer fluid	Yes

3.7.2 Safety

The collector provides for safe installation and mounting. It has no sharp edges, no loose connections, and no other potentially dangerous features	Yes
If the weight of the empty collector exceeds 60 kg an anchorage for a lifting device is included, except for collectors that are assembled on the roof	Yes
If the collector is made to be filled with a heat transfer fluid that is irritant to human skin or eyes or that is toxic, the collector carries a warning label	Yes

3.7.3 Installer instruction manual and/or technical datasheet

The collector is accompanied by an installer instruction manual	Yes

3.7.3.1 Information included in the installer instruction manual

Dimensions	Yes
Weight of the collector	Yes
Instructions about the transport and handling	Yes
Stagnation temperature at 1000 W/m^2 and 30 °C	Yes
Description of the mounting procedure	Yes
Recommendations about lightning protection	Yes
Instructions about the coupling of the solar collectors to one another	Yes
Instruction on the connection of the solar collector field to the heat transfer circuit	Yes
Instruction on dimensions of pipe connections for solar collector arrays	Yes
Reminder to follow the national requirements for the thermal insulation of the piping	Yes
Instructions about the heat transfer media which shall be used	Yes
Instructions and precautions which shall be taken during filling, operation and service	Yes
Pressure drop	Yes
Maximum and minimum tilt angle	Yes
Maximum operating pressure	Yes
Maximum operating temperature	Yes
Permissible positive and negative mechanical load	Yes
Maintenance requirements, including specific cleaning procedures if required	Yes
Indications about the requirements concerning free airflow on the backside of the collector	Yes
Indication on the impact resistance	Yes
Declaration of the climate class for testing	Yes

3.7.3.2 Information for building integrated collectors only

The collector can be used in building integrated systems as part of the building shell	No

If the collector can be integrated in the roof or in the building shell, the following recommendations shall be included in the instruction manual, to be considered when the collector is integrated in the roof or in the building shell.

Permanent stagnation over longer periods shall be avoided.	NA
The stagnation time between installation and commissioning of the system shall be less than one month.	NA
Ventilation behind the collector casing shall be sufficient and in accordance with national regulations and building codes.	NA
No additional isolation shall be added to the rear side of the collector.	NA
Piping near the collector shall be installed and isolated such that they are not in contact with wood or other inflammable materials.	NA
Preventive measures shall be taken to avoid that a leaking connection may lead to ingress of heat transfer fluid into the collector.	NA

3.7.4 Drawings and specifications

A complete set of technical drawings and datasheets has been submitted	Yes
Technical drawings and specifications	See Annex B

4 Test conditions and results

4.1 General remarks

Description of self-protection mechanism and description of adapted test procedure (for self-protecting collectors only, ISO 9806:2017, clause 5.2.2.3)	NA

4.2 Sampling

Sampling of the collector	From stock according to the Solar Keymark Scheme rules

4.3 Internal pressure test for fluid channels

4.3.1 General remarks

Test performed	Yes

4.3.2 Test condition

Test fluid	Water
Test temperature	20 °C ± 15 °C
Maximum test pressure	9 bar
Test duration	≥15 min

4.3.3 Test results

Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Other observations and remarks	None

4.4 Determination of standard stagnation temperature

4.4.1 General remarks

Test performed	Yes

One of the methods described in ISO 9806:2017 Clause 9.3 and Clause 9.4 can be used if the conditions described therein are fulfilled.
The standard stagnation temperature is reported in an up rounded 10 °C resolution.

4.4.2 If measured according to ISO 9806:2017 Clause 9.3

Test location	NA
Collector inclination	--
Average hemispherical irradiance	-- Wm^{-2}
Location for temperature sensor	--
Fluid specifications, flow rate, fluid temperature (if a fluid was circulated)	--
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	--
Observations and remarks:	--

4.4.3 If determined according to ISO 9806:2017 Clause 9.4

Maximum relative power output (Q/Q_{peak})	-0.0449
Irradiance at maximum relative power output	813.5 Wm^{-2}

4.4.4 Test results

Standard stagnation temperature at 1000 W/m^2 and 30 °C	70 °C

4.5 Exposure test

4.5.1 General remarks

Test performed	No
Test type	See remark on the test sequence under 2.1

4.5.2 Test conditions

Climate class	A
Irradiance G	≥1000 Wm^{-2}
Ambient air temperature ϑ_a	≥20 °C
Irradiation on collector H_x	≥600 MJ/m^2

4.5.2.1 Outdoor exposure

Location for initial outdoor exposure	--
Collector tilt angle during initial outdoor exposure	--
Collector azimuth angle during initial outdoor exposure (measured from due south)	--
Test date	--
Collector tested as façade collector	No
Test date in vertical position	--
Number of days in vertical position	--
Location of temperature measurement	No sensor
Total days of outdoor exposure	-- days
Total Hemispherical irradiation on collector	-- MJm^{-2}
Total time with conditions resulting in absorber temperature of the selected climate class	-- h

4.5.2.2 Additional exposure test using a fluid loop

Remark	Method not used
Fluid used	--
Flow rate	-- kgh^{-1}
Fluid temperature	-- °C
Test date	--
Location of temperature measurement	--
Total time with conditions resulting in absorber temperature of the selected climate class	-- h

4.5.2.3 Additional exposure test using a solar simulator

Remark	Method not used
Average radiation on collector plane	--
Average ambient temperature	--
Test date	--
Location of temperature measurement:	--
Total hemispherical irradiation on collector (incl. initial outdoor exposure)	--
Total time with conditions resulting in absorber temperature of the selected climate class	--

4.5.3 Test results

Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Other observations and remarks	None

4.6 External thermal shock test

4.6.1 General Remarks

Test performed	No

4.6.2 Test conditions

Climate class tested	--

4.6.2.1 Shock (1)

Test method	--
Collector tilt angle	--°
Irradiance during test average / minimum	-- / -- Wm^{-2}
Ambient air temperature average / minimum	-- / -- °C

4.6.2.2 Shock (2)

Test method	--
Collector tilt angle	--°
Irradiance during test average / minimum	-- / -- Wm^{-2}
Ambient air temperature average / minimum	-- / -- °C

4.6.3 Test results

Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	--
Observations and remarks	--

4.7 Internal thermal shock test

4.7.1 General remarks

Test performed	Yes

4.7.2 Test conditions

Climate class tested	Climate Class A

4.7.2.1 Shock (1)

Test method	Solar simulator, collector under stagnation conditions for ≥ 1 h before cold flushing
Collector tilt angle	45°
Irradiance during test average / minimum	1002.0 / 1001.2 Wm^{-2}
Ambient air temperature average / minimum	25.7 / 25.2 °C

4.7.2.2 Shock (2)

Test method	Solar simulator, collector under stagnation conditions for ≥ 1 h before cold flushing
Collector tilt angle	45°
Irradiance during test average / minimum	1005.2 / 1003.4 Wm^{-2}
Ambient air temperature average / minimum	27.0 / 26.8 °C

4.7.3 Test results

Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.8 Rain penetration test

4.8.1 General remarks

Test performed	Yes

4.8.2 Test conditions

Description of collector mounting	open rig
Collector tilt angle	10°

Number and position(s) of spray nozzles as defined in Fig. 2 and Fig. 3 of the ISO 9806:2017

4.8.3 Test results

Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.9 Freeze resistance test

4.9.1 General remarks

Test performed	No

4.10 Mechanical load test

4.10.1 Positive pressure test

4.10.1.1 General remarks

Test performed	Yes

4.10.1.2 Test conditions

Description of the collector mounting kit used in the test	See Annex A
Test method used to apply positive pressure	Pneumatic actuators with suction cups

4.10.1.3 Test results

Maximum test load without damage	2400 Pa
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.10.2 Negative pressure test

4.10.2.1 General remark

Test performed	Yes

4.10.2.2 Test conditions

Description of the collector mounting kit used in the test	See Annex A
Test method used to apply negative pressure	Pneumatic actuators with suction cups

4.10.2.3 Test results

Maximum negative test load without damage	2400 Pa
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.11 Impact resistance test

4.11.1 General remarks

Test performed	Yes

4.11.2 Test conditions

Test method	ice balls
Impact direction	horizontally

4.11.3 Test results

Maximum ball diameter without damage (if ice ball testing)	35 mm
Maximum drop height (1 digit precision) without damage (if steel ball testing)	N/A
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.12 Performance test results

4.12.1 General remarks

Parameters measured Yes

4.12.2 Collectors using external power sources (ISO 9806:2017 Clause 5.2.2.2)

Description of the required external power source N/A
Estimation of the energy consumption under normal operation: N/A

4.12.3 Thermal output measurements

4.12.3.1 Test conditions

Preconditioning Yes
Test method Steady-state outdoor
Heat transfer fluid for testing Water-glycol
Wind generator Yes
Orientation of the collector during test Portrait

4.12.3.2 Outdoor testing

Test location CH-8640 Rapperswil, 47.2 °N / 8.8 °O, 417 MAMSL
Collector orientation Tracked

4.12.3.3 Indoor testing (if applicable)

Type of lamps NR
Irradiance minimum / mean / maximum -- / -- / -- Wm^{-2}
Grid spacing for measuring irradiance data -- mm
Thermal irradiance* minimum / mean / maximum -- / -- / -- Wm^{-2}

4.12.4 Thermal performance reporting

4.12.4.1 Collector performance coefficients (based on gross area A_G)

The following collector coefficients shall be used for all thermal output calculations.

Collector performance coefficients	Result	Unit
A_g Collector gross area	1.95	m^2
$\eta_{0,hem}$ Collector efficiency based on hemispherical irradiance	0.512	- - -
$\eta_{0,b}$ Peak collector efficiency based on beam irradiance	0.517	- - -
K_d Incidence angle modifier for diffuse solar radiation	0.94	- - -
a_1 Heat loss coefficient	21.30	$Wm^{-2}K^{-1}$
a_2 Temperature dependence of the heat loss coefficient	0.0083	$Wm^{-2}K^{-2}$
a_3 Wind speed dependence of the heat loss coefficient	2.649	$Wsm^{-3}K^{-1}$
a_4 Sky temperature dependence of the heat loss coefficient	0.49	- - -
a_5 Effective thermal capacity incl. fluid (C/A_G)	14642	$Wsm^{-2}K^{-1}$
a_6 Wind speed dependence of the zero-loss efficiency	0.000	sm^{-1}
a_7 Wind speed dependence of IR radiation exchange	0.00	sm^{-1}
a_8 Radiation losses	0.000	$Wm^{-2}K^{-4}$
Average flowrate during the measurement	140	lh^{-1}

Where $\eta_{0,hem} = \eta_{0,b} (0.85 + 0.15 K_d)$ according to ISO 9806:2017 Annex B.

4.12.4.2 Power output per collector unit under SRC

The thermal output (Table 3) under standard reporting conditions (SRC) for the tested collector is calculated using formula:

$$\dot{Q} = A_G \begin{bmatrix} \eta_{0,b} K_b(\theta_L, \theta_T) G_b + \eta_{0,b} K_d G_d - a_1(\vartheta_m - \vartheta_a) - a_2(\vartheta_m - \vartheta_a)^2 - a_3 u'(\vartheta_m - \vartheta_a) + \\ a_4\left(E_L - \sigma T_a^4\right) - a_5(d\vartheta_m/dt) - a_6 u' G - a_7 u'\left(E_L - \sigma T_a^4\right) - a_8(\vartheta_m - \vartheta_a)^4 \end{bmatrix}$$

where u' = u – 3 ms^{-1} and

Climatic conditions	Blue sky	Hazy sky	Grey sky
G_b	850 Wm^{-2}	440 Wm^{-2}	0 Wm^{-2}
G_d	150 Wm^{-2}	260 Wm^{-2}	400 Wm^{-2}
ϑ_a	20 °C	20 °C	20 °C
$E_L - \sigma \cdot \vartheta_a^4$	−100 Wm^{-2}	−50 Wm^{-2}	0 Wm^{-2}
u	1,3 ms^{-1}	1,3 ms^{-1}	1,3 ms^{-1}

Table 2: Standard rating conditions (SRC)

$\vartheta_m - \vartheta_a$ [K]	ϑ_m [°C]	Blue sky [W]	Hazy sky [W]	Grey sky [W]
-10	10	1229	968	705
0	20	904	642	379
10	30	574	313	50
20	40	242	--	--
30	50	--	--	--

Table 3: Power output under standard rating conditions (SRC)

Maximum measured temperature difference 30.7 K
Power output data are valid for the maximum temperature difference 60 K
Peak Power per unit 904 W

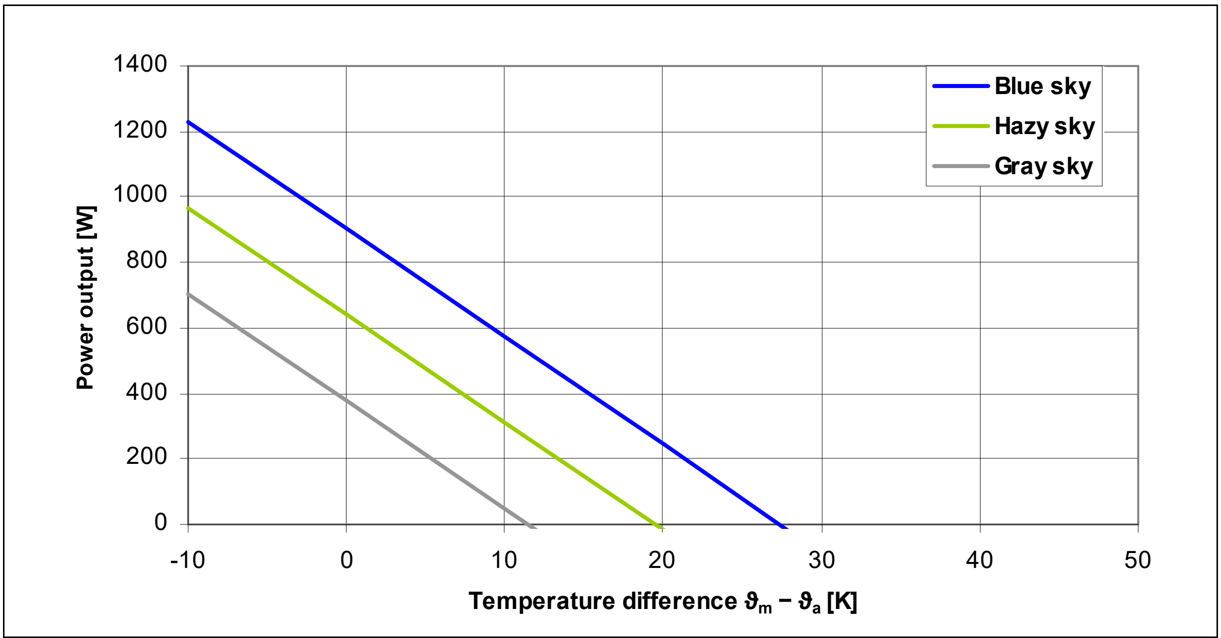


Figure 2: Power output per collector

4.13 Incidence angle modifier

4.13.1 General remarks

Parameters measured Yes

4.13.2 Test conditions

Test method Tracked steady state
Location Outdoor

4.13.3 Test results

Mathematical model for the transversal incidence angle modifier $K_T(\theta)$: Ambrosetti
Mathematical model for the longitudinal incidence angle modifier $K_L(\theta)$: Ambrosetti
Diffuse incidence angle modifier constant K_d (see ISO 9806:2017 Annex B) 0.94

	0	10	20	30	40	50	60	70	80	90
$K_b(\theta_T,0)$	1.00	1.00	1.00	1.00	0.99	0.98	0.93	0.83	0.58	0.00
$K_b(0,\theta_L)$	1.00	1.00	1.00	1.00	0.99	0.98	0.93	0.83	0.58	0.00

Table 4: table of incidence angle modifiers

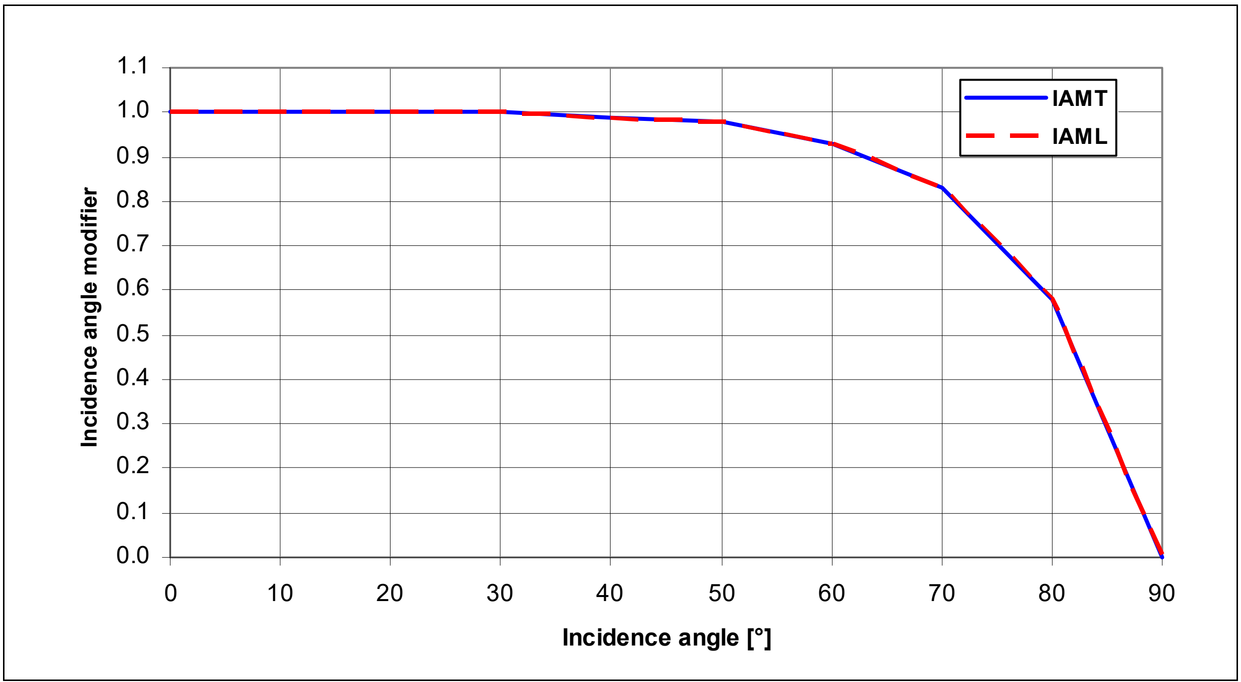


Figure 3: Incidence angle modifier

4.14 Effective thermal capacity

4.14.1 General remarks

Parameters measured	Yes

The effective thermal capacity is determined using two different methods of the ISO 9806:2017. In general, the lower of the two values is used for further performance calculations. The difference between the two methods is strongly depending on the collector type.

4.14.2 Measurement of the effective thermal capacity with irradiance

4.14.2.1 Test conditions

Test method	Measured according to ISO 9806:2017 Clause 25.2

4.14.2.2 Test results

Effective heat capacity (including fluid)	31053 $Wsm^{-2}K^{-1}$
Fluid	water-glycol
Effective heat capacity (without fluid)	26814 $Wsm^{-2}K^{-1}$

4.14.3 Calculation method for the determination of the effective thermal capacity

4.14.3.1 Test conditions

Test method	Calculated according to ISO 9806:2017 Clause 25.4

4.14.3.2 Test results

Effective heat capacity (including fluid)	14642 $Wsm^{-2}K^{-1}$
Fluid	water-glycol
Effective heat capacity (without fluid)	10403 $Wsm^{-2}K^{-1}$

4.15 Time constant

4.15.1 General remarks

Parameter measured	Yes

4.15.2 Test conditions

Test method	ISO 9806:2017 Clause 25.1, Heating up

4.15.3 Test results

Time constant, τ_c	241 s

4.16 Pressure drop measurements

4.16.1 General remarks

Parameter measured — Yes

The pressure drop was measured with the manufacturers corrugated tube connectors. Upon request the tubes were intentionally twisted to the maximum. The pressure drop was measured at different temperatures from 0°C to 30°C. As a comparison, the measurement was repeated with a straight corrugated tube.

4.16.2 Test conditions

Fluid used for the measurement — water-glycol
Fluid Temperatures (twisted tube) — 0,10,20,30 °C
Fluid Temperatures (straight tube) — 0 °C

4.16.3 Test results

Temperature (°C)	0 (straight)	0 (twisted)	10 (twisted)	20 (twisted)	30 (twisted)
Coefficient a ($Pahl^{-1}$)	97.6076	90.1658	58.96687	35.10506	23.416
Coefficient b (Pah^2l^{-2})	0.209301	0.252351	0.32618	0.378708	0.387643

Table 5: Pressure drop coefficients

The pressure drop for the tested collector using the test fluid is calculated using formula:

$$\Delta p = a\dot{V} + b\dot{V}^2$$

Pressure drop Pa - l/h	**50**	**100**	**150**	**200**	**250**
0 (straight)	5404	11854	19350	27894	37483
0 (twisted)	5139	11540	19203	28127	38313
10 (twisted)	3764	9158	16184	24841	35128
20 (twisted)	2702	7298	13787	22169	32446
30 (twisted)	2140	6218	12234	20189	30082

Table 6: Table of pressure drop data (Pascal)

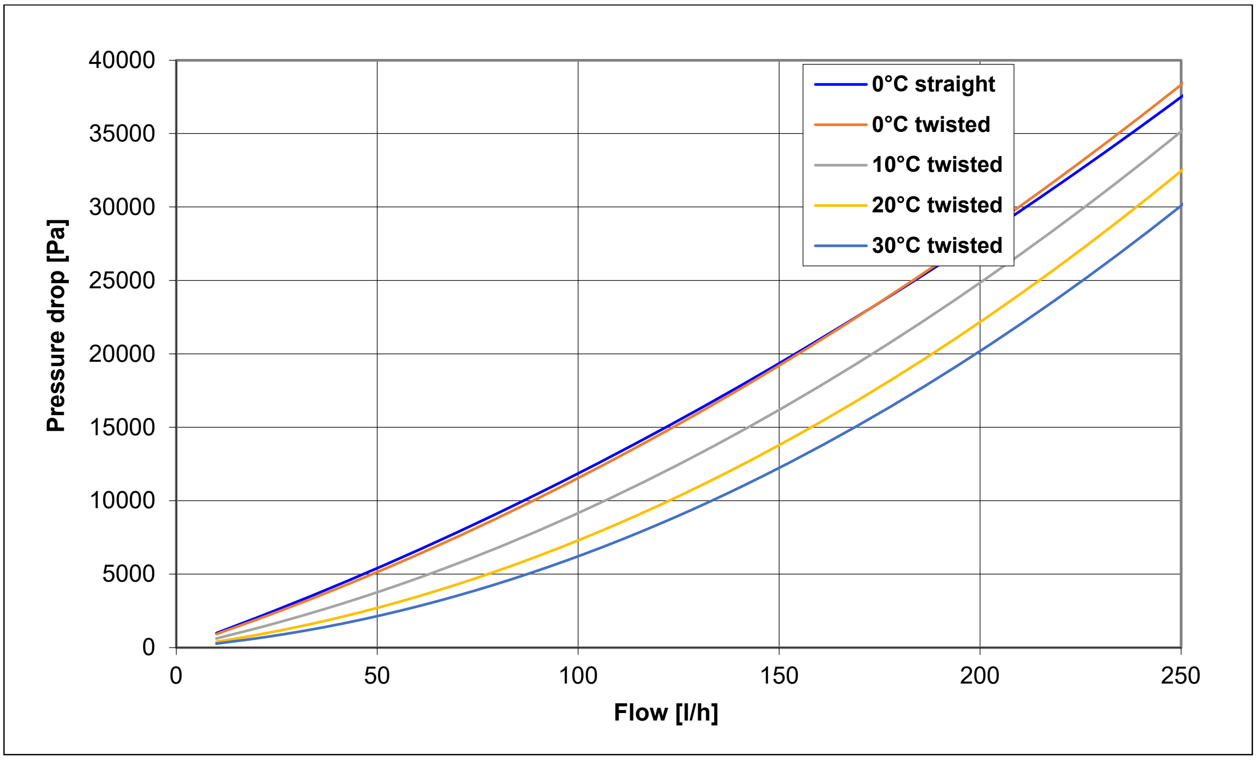


Figure 4: Pressure drop

4.17 Gross Thermal Yield (GTY)

The gross thermal yield of the collector is calculated at the indicated mean fluid temperature ϑ_m for the standard locations Athens, Davos, Stockholm and Würzburg.

	Athens			Davos			Stockholm			Würzburg		
Annual irradiation on collector plane	1765 kWh/m²			1630 kWh/m²			1166 kWh/m²			1244 kWh/m²		
Mean annual ambient air temp.	18.5°C			3.2°C			7.5°C			9.0°C		
Orientation	South, 25°			South, 30°			South, 45°			South, 35°		
ϑ_m	25°C	50°C	75°C	25°C	50°C	75°C	25°C	50°C	75°C	25°C	50°C	75°C
GTY (kWh/coll)	1177	23	-	283	-	-	331	1		392	4	-
GTY/A_G (kWh/m^2)	604	12	-	145	-	-	170	1	-	201	2	-
ΣGTY/A_G	1135 kWh/m^2											

Table 7: Gross thermal yield figures for selected locations

If the collector is member of a family as defined in C.1.2 of the EN 12975:2022, then the sum ΣGTY/A_G of the GTY's at the operating temperatures 25 °C, 50 °C and 75 °C at the four reference locations Würzburg, Stockholm, Davos and Athens, divided by the gross area of the collector shall be considered to determine the performance parameters of the whole family.

4.18 Gross Electric Yield (GEY)

The gross electric yield of the collector is calculated at the indicated mean fluid temperature ϑ_m for the standard locations Athens, Davos, Stockholm and Würzburg.

	Athens			Davos			Stockholm			Würzburg		
Annual irradiation on collector plane	1765 kWh/m²			1630 kWh/m²			1166 kWh/m²			1244 kWh/m²		
Mean annual ambient air temp.	18.5°C			3.2°C			7.5°C			9.0°C		
Orientation	South, 25°			South, 30°			South, 45°			South, 35°		
ϑ_m	25°C	50°C	75°C	25°C	50°C	75°C	25°C	50°C	75°C	25°C	50°C	75°C
GEY (kWh/coll)	739	675	610	686	626	566	487	445	402	521	475	430
GEY/A_G (kWh/m^2)	379	346	313	352	321	290	250	228	206	267	244	220

Table 8: Gross electric yield figures for selected locations

4.19 Final inspection

4.19.1 Test conditions

The collector was dismantled and inspected completely under laboratory conditions, i.e. in a non-operating condition, shaded from sunlight and at room temperature. Following the list in Table 9 but not limited to, all defects and abnormalities are documented and rated where applicable according to the following key as defined in ISO 9806:2017 Clause 17. Pictures of minor and major failures (if applicable) in 4.19.2

Collector component: Potential problem	Evaluation
a) Collector box/fasteners: Cracking/warping/corrosion/rain penetration/ permanent deformation / accumulation of humidity / etc.	0
b) Mountings/structure: Strength/safety/loosening/fatiguing/etc.	0
c) Seals/gaskets: Cracking/loss of adhesion/elasticity/brittleness/etc.	0
d) Cover: Cracking/breaking/crazing/buckling/delamination/permanent warping and deformation/outgassing/etc.	0
e) Absorber as a whole: Deformation/corrosion/buckling/etc.	0
f) Absorber coating: Cracking/crazing/blistering/discolouration/peeling/flaking/etc.	0
g) Reflectors: Deformation/cracking/crazing/blistering/discolourtion/buckling/peeling/flaking/etc.	0
h) Absorber tubes and headers/Flow passages/hoses inside the collector: Deformation/corrosion/leakage/loss of bonding/irreversible swelling/etc.	0
i) Absorber mountings: Permanent deformation/corrosion/rupture/etc.	0
j) Insulation: Water retention/outgassing/swelling/degradation/scorching/singeing/other detrimental changes that could adversely affect collector/performance/fouling/etc.	0
k) Corrosion and other deterioration caused by chemical action. Anywhere in the collector: Corrosion is considered severe if it impairs the function of the collector or if there is evidence that it will progress	0
l) Excessive retention of water anywhere in the collector	0
m) Heat pipes: Loss of fluid/loss of pressure/severe deformation/etc.	0
n) Self-protection systems: Any problem	0
o) Other components. Any other abnormality resulting in a reduction of thermal performance or service lifetime.	0

Table 9: Final inspection

0 No problem (or element is not existing)
1 Minor problem
2 Major failure

4.19.2 Test results

4.19.2.1 Major failures

A “major failure” rating is mandatory in case of (but not limited to):
- breaking or permanent deformation of the cover or the cover fixing;
- liquid channel leakage;
- any deformation such that permanent contact between absorber and cover is established;
- breaking or severe deformation of collector fixing points or of the collector box;
- vacuum loss, loss of gas filling
- dissolution of absorber coating
- accumulation of humidity in form of permanent condensate on the inside of the transparent cover or permanent local retention of water excessing 25 ml anywhere in the collector.

Test result	No major failure

Annex A Illustrations and photographs

Figure 5:
Typical collector field (photo by the manufacturer)

Figure 6:
Collector installed on the SPF solar simulator

Figure 7:
Collector installed on the SPF outdoor test rig

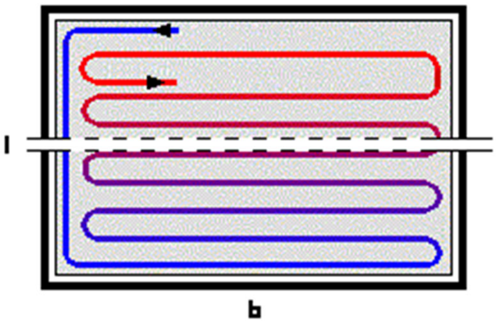


Figure 8:
Hydraulic flow scheme

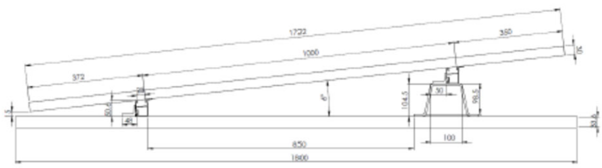


Figure 9:
Photo of collector mounting using the original mounting profiles and mounting parts.

Figure 10:
Collector under positive load test of 2400 Pa

Figure 11:
Collector under negative load test of 2400 Pa

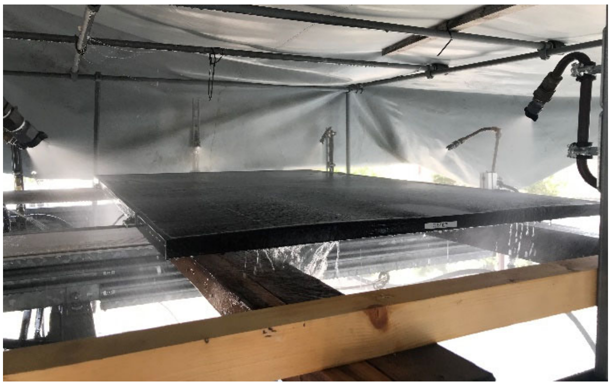


Figure 12:
Collector in rain test

Annex B Technical drawings and specifications

B.1 Technical drawings

Drawing number or drawing name	Date of revision
Solar Klemmprofil N87678	29.08.2022
Solar Sattelprofil N87677	26.08.2022
Kupferrohr	

Table 10: Technical drawings

B.2 Specifications

Document name	Date of revision
PV Module Datasheet in Annex C	Release BSMXXG12-54HPH(405-425W)-2022-01-Rev01-EN
Kupferrohr R1001	26.06.2018
Klebstoff Sikasil® AS-785 Produktdatenblatt	Version 3 (01 / 2014)
Sikasil® AS-785, Produkt Information für die Solar Industrie	Version 1 (07 / 2009)

Table 11: Specifications

B.3 Bill of materials

Document name	Date of revision
20230607_Stückliste BlackDiamond BSM-425_MG	2023.06.07

Table 12: Bill of materials

Annex C PV Module datasheet

BLUESUN

www.bluesunpv.com

182 HEX5

BSM425G12-54HPH

405~425W

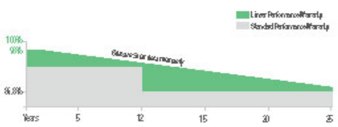
MONOFACIAL MODULE

BLUESUN SOLAR CO.,LTD

Bluesun, founded in 2004, as a superior photovoltaic manufacturer, is devoted to the R&D and the production of crystalline silicon solar cells and modules for 17 years. The company has its sales areas spread all over more than 100 countries and regions in the world, and the cumulative historical shipments exceeded 12 GW.

PERFORMANCE WARRANTY

- 12 Enhanced Product Warranty on Materials and Workman ship.
- 25 Linear Power Performance Warranty*
- 0.55 Annual Degradation Over 25 years no more than 0.55%



*According to the applicable Bluesun Solar Limited Warranty Statement.

MANAGEMENT SYSTEM CERTIFICATES

ISO 9001:2015 / Quality management system

ISO 14001:2015 / Standards for environmental

ISO 45001: 2018 / International standards for occupational health & safety

PRODUCT CERTIFICATES

IEC 61215 / IEC 61730 / CE

THE IDEAL SOLUTION FOR:

Rooftop arrays on residential buildings

High module conversion efficiency

MBB Half Cell Technology, new circuit design, lower internal current, lower Rs loss

Withstanding harsh environment

Reliable quality leads to a better sustainability even in harsh environment like desert, farm and coastline

PID Resistance

Excellent Anti-PID performance guarantee via optimized mass-production process and materials control

Excellent weak light performance

More power output in weak light condition, such as cloudy, morning and sunset

Extended wind and snow load tests

Module certified to withstand extreme wind (2400 Pa) and snow loads (5400 Pa)

BLUESUN SOLAR CO.,LTD

HEX 5

www.bluesunpv.com

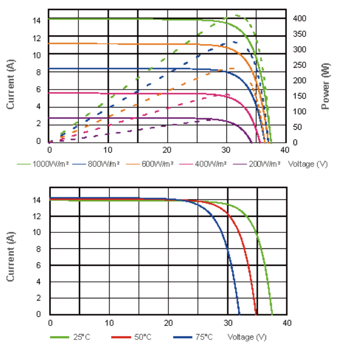
SPECIFICATIONS

Module Type	BSM405G12-54HPH		BSM410G12-54HPH		BSM415G12-54HPH		BSM420G12-54HPH		BSM425G12-54HPH	
	STC	NMOT	STC	NMOT	STC	NMOT	STC	NMOT	STC	NMOT
Maximum Power (Pmax/W)	405	302	410	306	415	310	420	314	425	318
Operating Voltage (Vmpp/V)	31.24	29.2	31.43	29.3	31.64	29.6	31.83	29.8	32.03	30.0
Operating Current (Impp/A)	12.97	10.36	13.05	10.42	13.13	10.48	13.21	10.54	13.29	10.60
Open-Circuit Voltage (Voc/V)	37.25	35.10	37.50	35.30	37.75	35.50	38.00	35.70	38.25	35.90
Short-Circuit Current (Isc/A)	13.86	11.17	13.94	11.24	14.02	11.30	14.10	11.36	14.18	11.42
Module Efficiency ηm(%)	20.7		21.0		21.3		21.5		21.7	

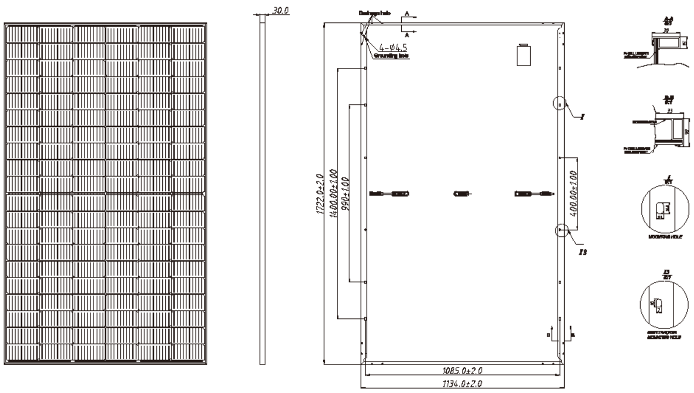
STC: Irradiance 1000W/m, Cell Temperature 25°C, Air Mass AM1.5 NMOT: Irradiance at 800W/m, Ambient Temperatue 20°C, Air Mass AM1.5, Wind Speed 1m/s

I-V CURVE

BSM410G12-54 HPH



ENGINEERING DRAWINGS



MECHANICAL SPECIFICATION

Cell Type	Monocrystalline
Cell Dimensions	182*182mm
Cell Arrangement	108 (6*18)
Weight	21.5kg
Module Dimensions	1722*1134*30mm
Cable Length	300mm
Cable Cross Section Size	TUV: 4mm² (0.006inches²)/UL: 12AWG
Front Glass	3.2mm (0.13inches) AR Coating Tempered Glass
No. of Bypass Diodes	3
Packing Configuration	36pcs/carton, 936pcs/40hq
Frame	Anodized Aluminium Alloy
Junction Box	IP68

OPERATING CONDITIONS

Maximun System Voltage	1000V/1500V/DC(IEC)
Operating Temperature	-40°C~ +85°C
Maximun Series Fuse	25A
Static Loading	Snow Loading: 5400Pa/ Wind Loading: 2400Pa
Conductivity at Ground	≤0.1Ω
Safety Class	II
Resistance	≥100MΩ
Connector	T01/LJQ-3-CSY/MC4/MC4-EVO2

TEMPERATURE COEFFICIENT

Temperature Coefficient Pmax	-0.35%/°C
Temperature Coefficient Voc	-0.26%/°C
Temperature Coefficient Isc	+0.048%/°C
NMOT	43±2°C

*Data contained in these specifications is subject to change without notice. Bluesun Solar reserves the right to final interpretation of content.

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