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Test Report No. C1744ISO

Solar thermal collector (liquid heating)
Standards: ISO 9806:2017, EN 12975-1:2010

Collector model: **FK Solinas 3**

Test ordered by:

FK Solartechnik GmbH
Industriepark Kleinkoschen

D-01968 Senftenberg

Manufacturer:

FK Solartechnik GmbH
Industriepark Kleinkoschen

D-01968 Senftenberg

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 12975-1:2010.
This test report is made according to the requirements of ISO 9806:2017, EN 12975-1:2010.
This test report fulfils the requirements of ISO 17025.

Rapperswil, 16. March 2019

Dr. Andreas Bohren
Head of SPF Testing

Dipl.-Ing. Walter Gubler
Test engineer

The validity and authenticity of this report can be checked anytime
www.spf.ch/i-Report Name: iC1744ISOe.pdf Password: w4Y9zJ2E

1 Summary and main results

Clause in ISO 9806:2017 / Test		Date	Results/Observations	
--	Random sampling	16.08.2017	- - -	
--	Delivery of test sample(s)	23.08.2017	- - -	
--	Initial visual inspection	23.08.2017	- - -	0
6	Internal pressure	10.07.2018	15 bar	0
9	Standard stagnation temperature	27.04.2018	230 °C	0
10	Exposure or half-exposure	28.03.2018 – 12.6.2018	Climate class A	0
11	External thermal shock 1 / 2	20.04.2018 / 07.05.2018	Climate class A	0
12	Internal thermal shock 1 / 2	18.04.2018 / 19.04.2018	Climate class A	0
13	Rain penetration	26.06.2018	- - -	0
14	Freeze resistance	05.11.2018	NR	-
15	Mechanical load (positive) 1 / 2	06.07.2018	1500 Pa	0
15	Mechanical load (negative) 1 / 2	06.07.2018	1500 Pa	0
16	Impact Resistance	10.07.2018	25 mm (ice ball)	0
27	Pressure drop	15.05.2018	- - -	-
19	Thermal performance	11.01.2018 - 24.04.2018	- - -	0
	A_G Collector gross area		2.267 m^2	-
	$\eta_{0,hem}$ Collector efficiency based on hemispherical irradiance		0.398	-
	$\eta_{0,b}$ Peak collector efficiency based on beam irradiance		0.392	-
	K_d Incidence angle modifier for diffuse solar radiation		1.108	-
	a_1 Heat loss coefficient		1.29 $Wm^{-2}K^{-1}$	-
	a_2 Temperature dependence of the heat loss coefficient		0.0014 $Wm^{-2}K^{-2}$	-
	a_3 Wind speed dependence of the heat loss coefficient		0.00 $Wsm^{-3}K^{-1}$	-
	a_4 Sky temperature dependence of the heat loss coefficient		0.00	-
	a_5 Effective thermal capacity incl. fluid (C/A_G)		8249 $Wsm^{-2}K^{-1}$	-
	a_6 Wind speed dependence of the zero loss efficiency		0.00 sm^{-1}	-
	a_7 Wind speed dependence of IR radiation exchange		0.00 sm^{-1}	-
	a_8 Radiation losses		0.00 $Wm^{-2}K^{-4}$	-
	Average flowrate during the measurement		170.0 lh^{-1}	-

26	Incidence angle	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	
26	$K_b(\theta_T,0)$	1.00	1.01	1.06	1.15	1.30	1.47	1.42	1.11	0.60	0.00	-
26	$K_b(0, \theta_L)$	1.00	1.00	1.00	1.00	0.99	0.96	0.90	0.78	0.53	0.00	-

25	Time constant	07.05.2018	595 s	-
17	Final inspection	11.07.2018 / 05.11.2018	- - -	0

Table 1: Summary of results and events

Content page

2 Introduction

2.1 Remarks on the test sequence

None

2.2 Test standards

The collector was tested according to the standards
- ISO 9806:2017
- EN 12975-1:2010

and in full compliance with the Solar Keymark scheme rules.

The results are presented in this report.
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 Failure (description see 4.16)
1	Minor Failure (description see 4.16)
2	Major failure (description see 4.16)

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 Instruments and test devices

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	FK Solartechnik GmbH
Collector name	FK Solinas 3
Additional brand names (if applicable)	See Annex G
Collector type	Evacuated tubular collector
Serial No of test sample(s)	110359 /110321
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
On flat roof	No
In tilted roof	No
Façade	Yes
On Stand	Yes
Schematic diagram of collector mounting	See Figure 8

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

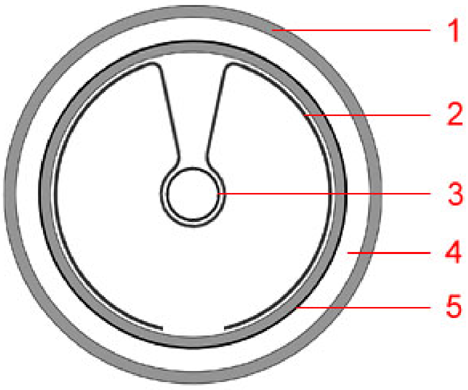
Minimum / Maximum operation temperature	NS / 217 °C
Maximum operation pressure (at maximum temperature of operation)	$6x10^5$ Pa (6 bar)
Minimum / Maximum installation inclination	25° / 90°
Recommended heat transfer fluid(s)	glycol – water mixtures
Additional remarks concerning the heat transfer fluid(s)	--
Flow rate minimum / recommended / maximum	18 / 30 / 170 lh^{-1}
Other limitations	--

3.5 Dimensions and general information

Gross length (length from bottom to top, orientation as tested)	1907 mm
Gross width (width from left to right, orientation as tested)	1189 mm
Gross height	136 mm
Gross area, A_G (as defined in ISO 9488)	2.267 m^2
Aperture area, A_{Ap} (as defined in ISO 9488)	1.396 m^2
Absorber area, A_{Abs} (as defined in ISO 9488)	1.210 m^2
Weight empty	47 kg
Fluid content	0.98 l

3.6 Specifications on elements

3.6.1 Collector cross section



Legend
1 Glazing
2 Heat-conducting metal sheet
3 Heat pipe
4 Vacuum
5 Absorber
5 Absorber coating

Figure 1: Collector cross section

3.6.2 Frame, enclosure, casing

Legend No	--
Construction type	Casing
Enclosure material	Aluminium / Plastic
Thickness	1.5 mm
Joining method	screwed

3.6.3 Absorber

Legend No	5
Material	Evacuated double glass tube
Number of absorber elements (fins, tubes, etc.)	15
Distance between absorber elements	74 mm
Absorber element length / width	1725 / 47 mm
Absorber total length / width	1725 / 705 mm
Absorber thickness	1.5 mm
Absorber coating	Al-N/SS/Cu
Absorber coating trade name	--
Solar absorptance α / Hemispherical emittance ε	93% / 7%
Bond between riser and fin/plate	--

3.6.4 Hydraulic system

Flow pattern	Serial, See Figure 7
Number of risers	--
Riser material	--
Riser length	--
Riser diameter outer / inner	--
Distance between risers	--
Manifold material	Copper
Manifold length	1260 mm
Manifold diameter outer / inner	35 / 32 mm
Collector hydraulic connector type/size	Tube / 22 mm

3.6.5 Transparent cover(s)

Legend No	1
Material	Borosilicate glass
Number of serial glazing	1
Thickness	1.8 mm
Diameter (for tube collectors only) outer / inner	57.8 / 54.2 mm
Solar transmittance	--
Glazing surface characteristics	not structured

3.6.6 Insulation(s)

Legend No	--
Material	Rockwool / Polyurethane foam
Cover	--
Thickness	30 mm
Thermal conductivity (50°C)	-- $Wm^{-1}K^{-1}$

3.6.7 Heat pipes

Legend No	3
Material	Copper
External diameter of pipe and condenser	8 /14 mm
Liquid type	Inorganic salt
Liquid mass	5 g

3.6.8 Reflector

Legend No	--
Type of reflector (CPC, Flat, etc.)	NR
Material	NR
Length / width	-- mm / -- mm
Reflectance (hemispherical)	-- %
Reflectance (diffuse)	-- %

3.6.9 Other elements

Heat-conducting metal sheet (Legend No. 2)	Aluminum
Vacuum (Legend No. 4)	--

3.7 Technical documentation and safety requirements (EN 12975)

3.7.1 Labelling

The collector carries a visible and durable label.	Yes

3.7.1.1 Information on the label

Name of manufacturer	Yes
Collector type	Yes
Serial number	Yes
Year of production	Yes
Gross area of collector	Yes
Maximum operating pressure	Yes
Stagnation temperature at 1000 W/m² and 30 °C	Yes
Volume of heat transfer fluid	Yes
Weight of empty collector	Yes
Made in ...	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

The collector is accompanied by an installer instruction manual.	Yes

3.7.3.1 Information included in the installer instruction manual

Dimensions and weight of the collector	Yes
Instructions about the transport and handling	Yes
Description of the mounting procedure	Yes
Recommendations about lightning protection	Yes
Instructions about the coupling of several collectors (up to 20 m²).	Yes
Instructions for the connection of the collector field to the heat transfer circuit (up to 20 m²).	Yes
Instructions for the dimension of the pipe connections for collector arrays (up to 20 m²).	Yes
Recommendation about the heat transfer fluid (also with respect to corrosion)	Yes
Precautions to be taken during filling, operation and service.	Yes
Maximum operating pressure	Yes
Pressure drop	Yes
Maximum and minimum tilt angle	Yes
Permissible wind and snow loads	Yes
Maintenance requirements	Yes
The documentation is available in the national language of the country where the collector is sold. (Manufacturers' information)	Yes

3.7.4 Drawings and specifications

A complete set of technical drawings and datasheets has been submitted	Yes
Drawings and specifications	See Annex C

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 Internal pressure test for fluid channels

4.2.1 General remarks

Test performed	Yes

4.2.2 Test condition

Test fluid	Water
Test temperature	20 °C ± 15 °C
Test duration	≥15 min

4.2.3 Test results

Maximum test pressure	15 bar
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Other observations and remarks	None

4.3 Determination of standard stagnation temperature

4.3.1 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.

4.3.2 If measured according to ISO 9806:2017 Clause 9.3

Test location	Rapperswil (CH), 47.2 °N / 8.8 °E, 417 MAMSL
Collector inclination	42°
Average ambient temperature	21.7 °C
Average hemispherical irradiance	1000.1 Wm^{-2}
Location for temperature sensor	Temperature sensor attached to the manifold tube
Fluid specifications, flow rate, fluid temperature (if a fluid was circulated)	NA
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks:	None

4.3.3 If determined according to ISO 9806:2017 Clause 9.4

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

4.3.4 Test results

Standard stagnation temperature at 1000 W/m^2 and 30 °C	230 °C

4.4 Exposure test

4.4.1 General remarks

Test performed	Yes
Test type	Full exposure

4.4.2 Test conditions

Climate class	A
G	≥1000 Wm^{-2}
ϑ_a	≥20 °C

4.4.2.1 Outdoor exposure

Location for initial outdoor exposure	CH-8640 Rapperswil, 47.2 °N / 8.8 °O, 417 MAMSL
Collector tilt angle during initial outdoor exposure	30 - 90°
Collector azimuth angle during initial outdoor exposure (measured from due south)	tracked
Test date	28.03.2018 – 12.6.2018
Collector tested as façade collector	Yes
Location of temperature measurement	Temperature sensor attached to the manifold tube
Total days of outdoor exposure	45 days
Total hemispherical irradiation on collector	897.6 MJm^{-2}
Total time with conditions resulting in absorber temperature for climate class A	33.2 h

4.4.2.2 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	NA

4.4.2.3 Additional exposure test using a solar simulator

Remark	Method not used
Average radiation on collector plane	-- Wm^{-2}
Average ambient temperature	-- °C
Test date	--
Location of temperature measurement	NA

4.4.3 Test results

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

4.5 External thermal shock test

4.5.1 General Remarks

Testing is not mandatory for collectors using toughened glass.
To comply with ISO 9806:2013 the external thermal shocks were made anyway.

Test performed	Yes

4.5.2 Test conditions

Climate class tested	A
G	≥ 1000 Wm^{-2}
ϑ_a	≥ 20 °C

4.5.2.1 Shock (1)

Test method	Outdoor. Collector operated under stagnation conditions for ≥ 1 h
Collector tilt angle	41.8
Irradiance during test average / minimum	1006 / 892 Wm^{-2}
Ambient air temperature average / minimum	26.0 / 25.4 °C

4.5.2.2 Shock (2)

Test method	Outdoor. Collector operated under stagnation conditions for ≥ 1 h
Collector tilt angle	33.2
Irradiance during test average / minimum	1012 / 988 Wm^{-2}
Ambient air temperature average / minimum	24.1 / 22.9 °C

4.5.3 Test results

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

4.6 Internal thermal shock test

4.6.1 General remarks

Test performed	Yes

4.6.2 Test conditions

Climate class tested	A
G	≥ 1000 Wm^{-2}
ϑ_a	≥ 20 °C

4.6.2.1 Shock (1)

Test method	Indoor solar simulator. Collector operated under stagnation conditions for ≥ 1 h
Collector tilt angle	39.1 °
Irradiance during test average / minimum	1043 / 1006 Wm^{-2}
Ambient air temperature average / minimum	23.8 / 22.9 °C

4.6.2.2 Shock (2)

Test method	Indoor solar simulator. Collector operated under stagnation conditions for ≥ 1 h
Collector tilt angle	45.0 °
Irradiance during test average / minimum	1018 / 984 Wm^{-2}
Ambient air temperature average / minimum	21.2 / 20.4 °C

4.6.3 Test results

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

4.7 Rain penetration test

4.7.1 General remarks

Test performed	Yes

4.7.2 Test conditions

Description of collector mounting	open frame
Collector tilt angle	5°
Number and description of position(s) of spray nozzles	4 nozzles as in Fig. 2 of ISO 9806:2017

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 Freeze resistance test

4.8.1 General remarks

Test performed	Yes

4.8.2 Test conditions

Collector type	heat pipe collector
Collector tilt angle	90°

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 Mechanical load test

4.9.1 Positive pressure test

4.9.1.1 General remarks

Test performed	Yes

4.9.1.2 Test conditions

Description of the collector mounting kit used in the test	See Annex A
Test method used to apply positive pressure	Evenly distributed water bags

4.9.1.3 Test results

Maximum test load without damage	1500 Pa
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.9.2 Negative pressure test

4.9.2.1 General remark

Test performed	Yes

4.9.2.2 Test conditions

Description of the collector mounting kit used in the test	See Annex A
Test method used to apply negative pressure	Evenly distributed water bags

4.9.2.3 Test results

Maximum negative test load without damage	1500 Pa
Any evident problems, damages and failures according to ISO 9806:2017 Clause 17	None
Observations and remarks	None

4.10 Impact resistance test

4.10.1 General remarks

Test performed	Yes

4.10.2 Test conditions

Test method	ice ball test
Impact direction	horizontal

4.10.3 Test results

Maximum ball diameter without damage (if ice ball testing)	25 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

4.11 Performance test results

4.11.1 General remarks

Parameters measured: Yes

4.11.2 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

4.11.3 Thermal output measurements

4.11.3.1 Test loop

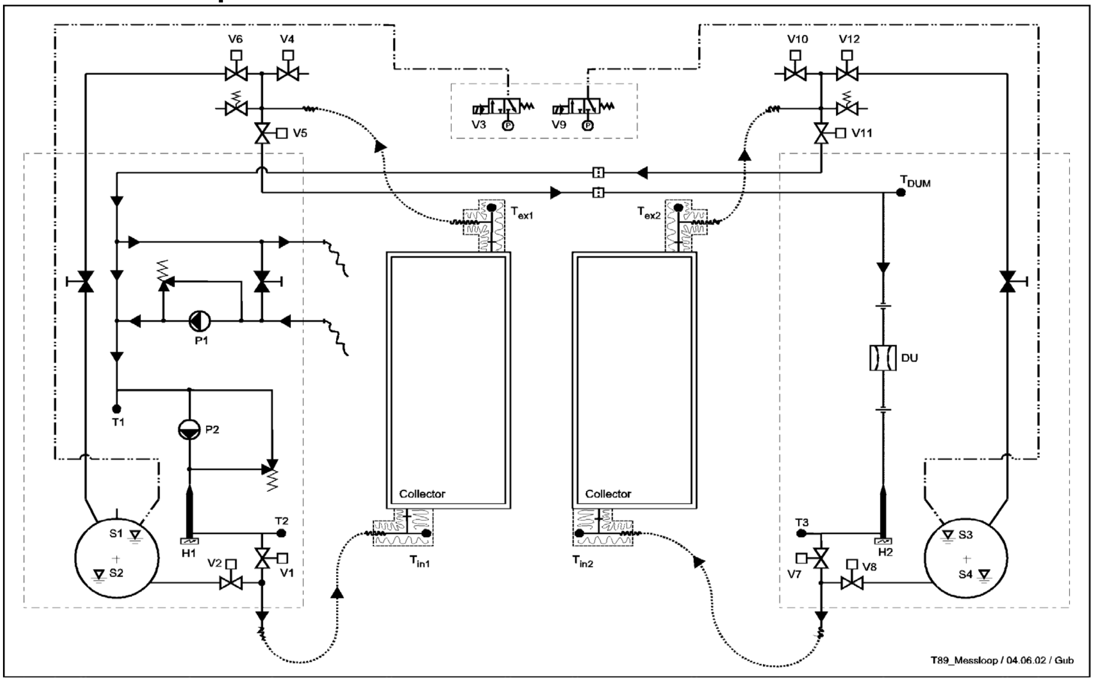


Figure 2: Schematic of the test loop for thermal performance measurements.

4.11.3.2 Test conditions

Preconditioning	Yes
Test method	outdoor testing, steady state on solar tracker
Heat transfer fluid for testing	water-glycol
Wind generator	Yes
Orientation of the collector during test	portrait

4.11.3.3 Outdoor testing

Test location	Rapperswil (CH), 47.2° N / 8.8° E, 417 MAMSL
Collector orientation	tracked

4.11.3.4 Indoor testing (if applicable)

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

*measured over the collector

4.11.4 Thermal performance reporting

4.11.4.1 Collector performance coefficients (based on gross area A_G)m2

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

Collector performance coefficient	Result	SDev	Unit
A_g Collector gross area	2.267	±2e-6	m^2
$\eta_{0,hem}$ Collector efficiency based on hemispherical irradiance	0.398	±0.001	- - -
$\eta_{0,b}$ Peak collector efficiency based on beam irradiance	0.392	±0.001	- - -
K_d Incidence angle modifier for diffuse solar radiation	1.108	±0.001	- - -
a_1 Heat loss coefficient	1.29	±0.04	$Wm^{-2}K^{-1}$
a_2 Temperature dependence of the heat loss coefficient	0.0014	±0.00	$Wm^{-2}K^{-2}$
a_3 Wind speed dependence of the heat loss coefficient	0.00	--	$Wsm^{-3}K^{-1}$
a_4 Sky temperature dependence of the heat loss coefficient	0.00	--	- - -
a_5 Effective thermal capacity (C/A_G)	8249	--	$Wsm^{-2}K^{-1}$
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	170.0	--	lh^{-1}

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

The indicated Standard deviations are based on the sensors and the measured data. Systematic uncertainties are not included.

4.11.4.2 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:

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

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	932	676	423
0	20	903	647	394
10	30	873	617	364
20	40	843	587	334
30	50	812	556	303
40	60	781	525	272
50	70	749	493	240
60	80	716	460	207
70	90	683	427	174
80	100	649	393	140
90	110	614	358	105
100	120	579	323	70
110	130	543	287	34
120	140	506	250	-
130	150	469	213	-

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

Maximum measured temperature difference	90.5 K
Power output data are valid for the maximum temperature difference	130 K
Peak Power per unit	903 W

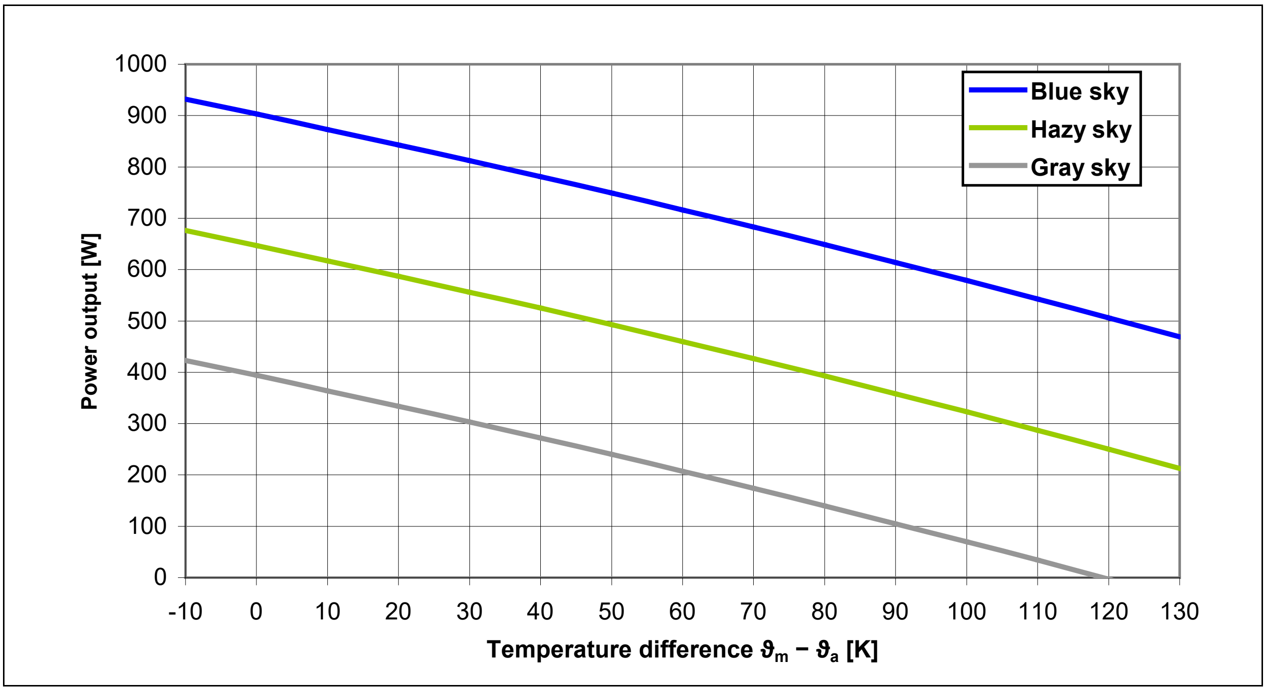


Figure 3: Power output per collector

4.12 Incidence angle modifier

4.12.1 General remarks

Parameters measured — Yes

4.12.2 Test conditions

Test method — tracked steady state
Location — outdoor

4.12.2.1 Additional information for indoor testing only

Type of lamps — NR
Irradiance* minimum / mean / maximum — -- / -- / -- Wm^{-2}
Grid spacing for measuring irradiance, collimation and thermal irradiance — -- mm
Collimation* minimum / mean / maximum — -- / -- / -- Wm^{-2}
Thermal irradiance* minimum / mean / maximum — -- / -- / -- Wm^{-2}
* measured over the collector

4.12.3 Test results

Mathematical model for the transversal incidence angle modifier $K_T(\theta)$: — Cubic spline function
Mathematical Model for the longitudinal incidence angle modifier $K_L(\theta)$: — Cubic spline function
Diffuse incidence angle modifier constant K_d (see ISO 9806:2017 Annex B) — 1.108

	0	10	20	30	40	50	60	70	80	90
$K_b(\theta_T,0)$	1.00	1.01	1.06	1.15	1.30	1.47	1.42	1.11	0.60	0.00
$K_b(0,\theta_L)$	1.00	1.00	1.00	1.00	0.99	0.96	0.90	0.78	0.53	0.00

Table 4: table of incidence angle modifiers

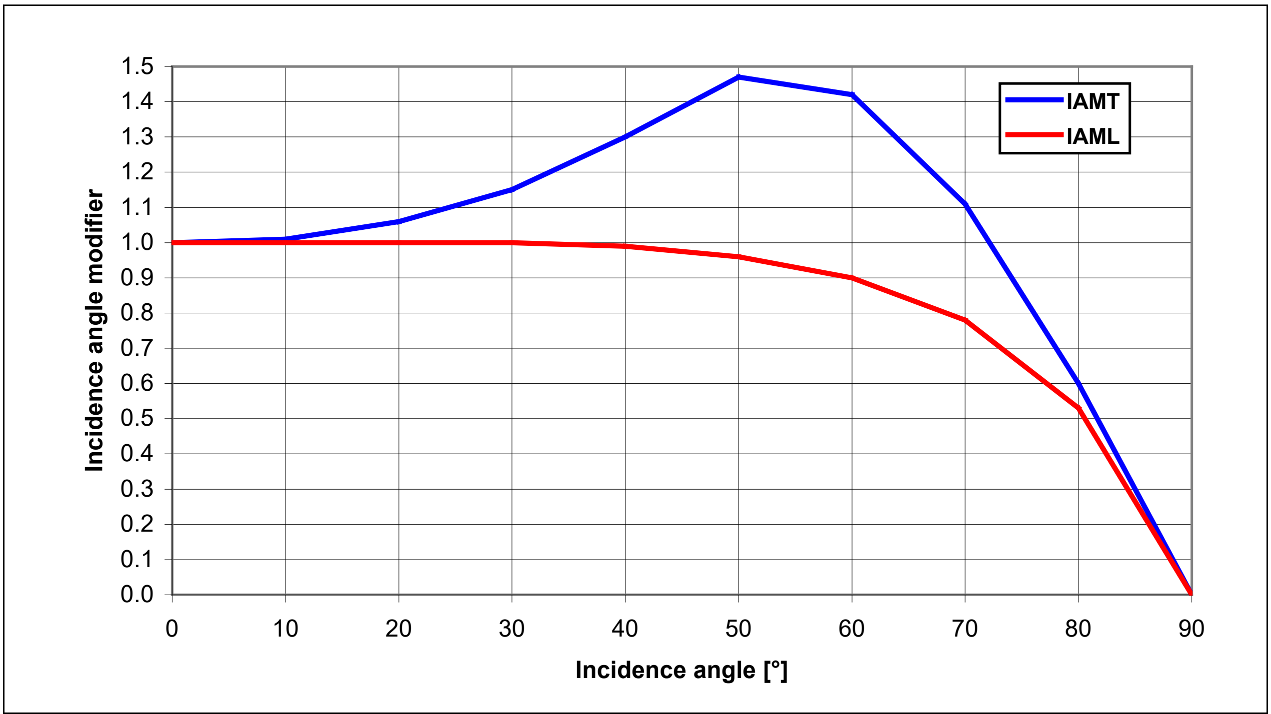


Figure 4: Incidence angle modifier

4.13 Effective thermal capacity

4.13.1 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.

4.13.2 Measurement of the effective thermal capacity with irradiance

4.13.2.1 Test conditions

Test method	Measured according to ISO 9806:2017 Clause 25.2

4.13.2.2 Test results

Effective heat capacity (including fluid)	144'684 $Wsm^{-2}K^{-1}$
Fluid	water-glycol
Effective heat capacity (without fluid)	143'052 $Wsm^{-2}K^{-1}$

4.13.3 Calculation method for the determination of the effective thermal capacity

4.13.3.1 Test conditions

Test method	Calculated according to ISO 9806:2017 Clause 25.4

4.13.3.2 Test results

Effective heat capacity (including fluid)	8'249 $Wsm^{-2}K^{-1}$
Fluid	water-glycol
Effective heat capacity (without fluid)	6'617 $Wsm^{-2}K^{-1}$

4.14 Time constant

4.14.1 General remarks

Parameter measured	Yes

4.14.2 Test conditions

Test method	ISO 9806:2017 Clause 25.5 Heating up

4.14.3 Test results

Time constant, τ_c	595 s

4.15 Pressure drop measurements

4.15.1 General remarks

Parameter measured: Yes

4.15.2 Test conditions

Fluid used for the measurement: Water-glycol
Fluid Temperature: 20 °C

4.15.3 Test results

Pressure drop coefficient a: 1.29444 $Pahl^{-1}$
Pressure drop coefficient b: 0.00948963 Pah^2l^{-2}

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 - L/h	0	50	100	150	200	250	300
Pa	0	88	224	408	638	917	1242
mbar	0	0.88	2.24	4.08	6.38	9.17	12.42

Table 5: Table of pressure drop data

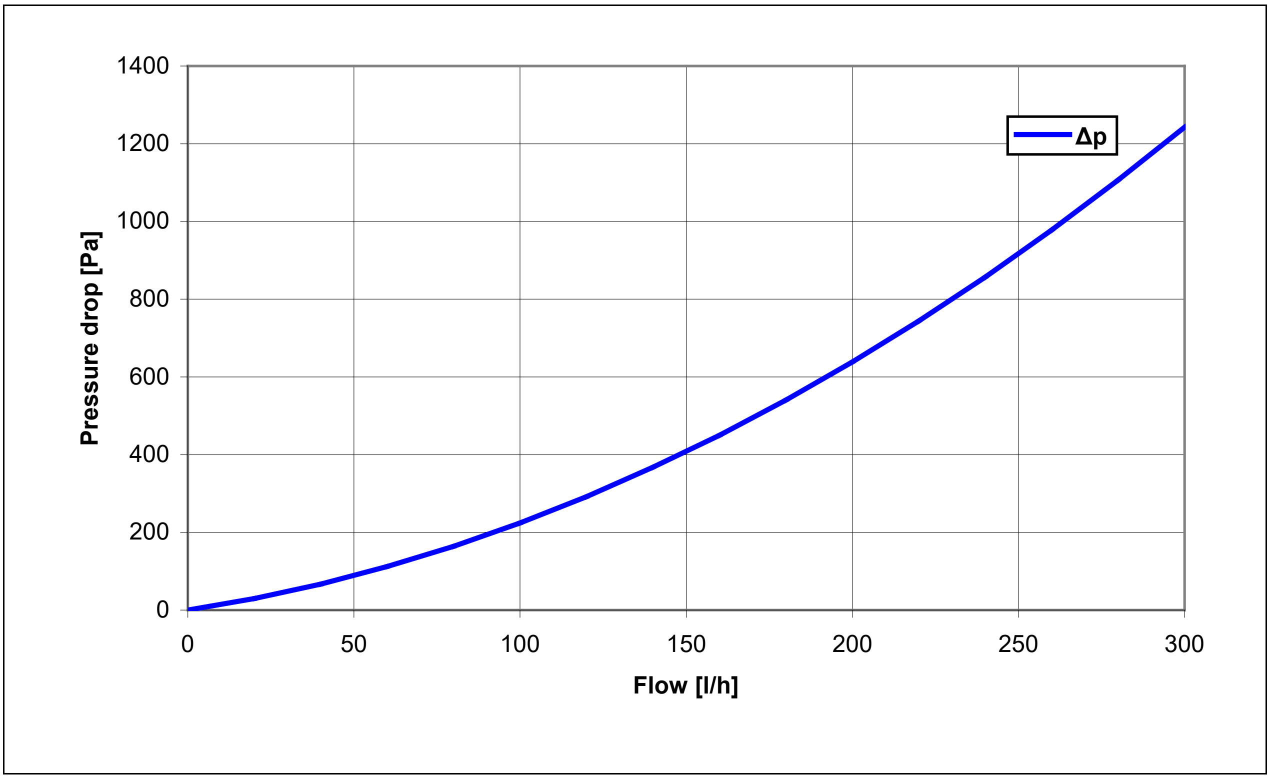


Figure 5: Pressure drop

4.16 Final inspection

The collector was dismantled and inspected completely under laboratory conditions, i.e. in a non-operating condition, shaded from light and at room temperature. Following the list in Table 6 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 Annex A

0 No problem (or element is not existing)

1 Minor problem

2 Major failure

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 life time.	0

Table 6: Final inspection

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.

4.16.1 Test results

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

Annex A Illustrations and photographs

Figure 6: Photograph of the collector

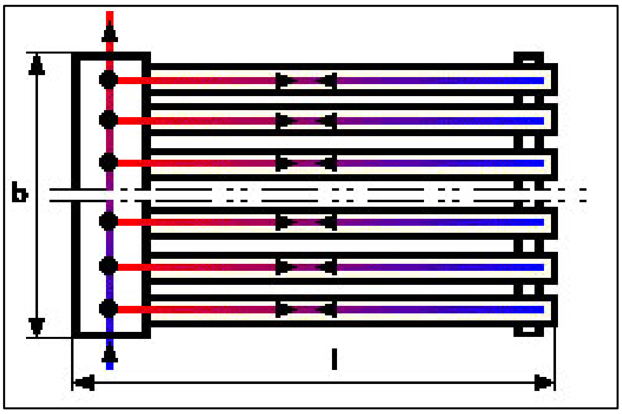


Figure 7: Hydraulic flow scheme

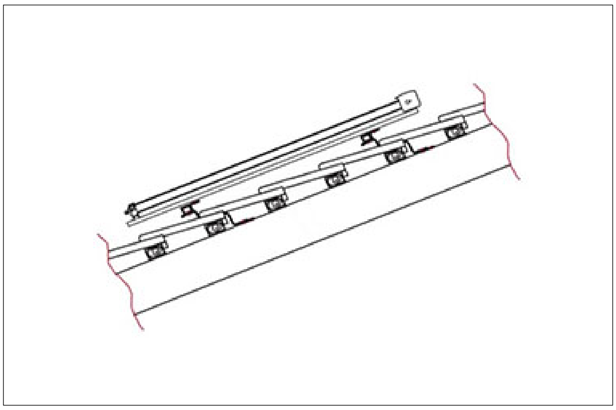


Figure 8: Schematic diagram of collector mounting

Annex B Climatic data for exposure

Date	H [MJ/m²]	ϑ_{amb} [°C]	ΣH [MJ/m²]	Location	Day index
28.03.2018	6.1	8.4	6.1	outdoor	1
29.03.2018	7.1	7.0	13.2	outdoor	2
30.03.2018	22.4	6.9	35.6	outdoor	3
31.03.2018	5.6	5.1	41.2	outdoor	4
01.04.2018	7.1	7.4	48.3	outdoor	5
02.04.2018	25.7	10.2	74.0	outdoor	6
03.04.2018	24.6	13.2	98.5	outdoor	7
04.04.2018	19.4	11.9	118.0	outdoor	8
05.04.2018	15.0	10.2	132.9	outdoor	9
06.04.2018	36.5	10.2	169.5	outdoor	10
07.04.2018	35.6	13.4	205.1	outdoor	11
08.04.2018	30.4	15.7	235.5	outdoor	12
09.04.2018	10.1	15.5	245.5	outdoor	13
10.04.2018	21.8	12.1	267.3	outdoor	14
11.04.2018	27.4	11.4	294.7	outdoor	15
12.04.2018	24.2	15.0	318.9	outdoor	16
13.04.2018	29.1	14.1	348.0	outdoor	17
14.04.2018	27.2	13.4	375.2	outdoor	18
15.04.2018	15.5	13.0	390.7	outdoor	19
16.04.2018	6.3	13.1	397.0	outdoor	20
17.04.2018	35.0	15.6	432.0	outdoor	21
18.04.2018	36.7	19.1	468.8	outdoor	22
19.04.2018	36.2	20.1	504.9	outdoor	23
20.04.2018	34.5	21.4	539.4	outdoor	24
21.04.2018	35.4	22.5	574.8	outdoor	25
22.04.2018	33.3	23.2	608.1	outdoor	26
23.04.2018	20.0	20.3	628.1	outdoor	27
24.04.2018	32.8	19.8	660.8	outdoor	28
25.04.2018	28.8	20.8	689.6	outdoor	29
26.04.2018	4.1	12.3	693.7	outdoor	30
29.05.2018	6.9	21.2	700.6	outdoor	31
30.05.2018	16.6	24.9	717.2	outdoor	32
31.05.2018	16.8	23.6	733.9	outdoor	33
01.06.2018	17.6	22.8	751.5	outdoor	34
02.06.2018	20.6	23.6	772.1	outdoor	35

03.06.2018	15.3	25.0	787.3	outdoor	36
04.06.2018	12.4	24.4	799.7	outdoor	37
05.06.2018	20.6	24.0	820.3	outdoor	38
06.06.2018	11.4	22.7	831.7	outdoor	39
07.06.2018	11.1	24.0	842.9	outdoor	40
08.06.2018	9.4	23.4	852.3	outdoor	41
09.06.2018	19.0	25.0	871.3	outdoor	42
10.06.2018	16.2	26.6	887.5	outdoor	43
11.06.2018	6.7	22.4	894.2	outdoor	44
12.06.2018	3.4	20.3	897.6	outdoor	45

Table 7: Climatic conditions for all days during the test

Date / Time	G [W/m²]	ϑ_{amb} [°C]	Δt [min]	Location	Sum [min]
04.04.2018 10:56:00-13:35:00	1049.5	18.7	159.0	outdoor	159.0
05.04.2018 14:54:00-15:28:00	1098.7	13.4	34.0	outdoor	193.0
06.04.2018 11:35:30-12:51:00	1086.0	11.3	75.5	outdoor	268.5
06.04.2018 12:53:30-13:44:30	1046.6	13.0	51.0	outdoor	319.5
06.04.2018 14:06:30-16:01:00	1036.4	15.7	114.5	outdoor	434.0
07.04.2018 11:39:30-12:15:00	1029.9	14.9	35.5	outdoor	469.5
07.04.2018 12:16:00-13:09:00	1024.6	16.3	53.0	outdoor	522.5
07.04.2018 14:20:30-15:52:30	1006.1	20.5	92.0	outdoor	614.5
11.04.2018 11:52:30-12:45:30	1064.0	13.7	53.0	outdoor	667.5
11.04.2018 13:16:00-14:22:30	1058.2	16.8	66.5	outdoor	734.0
13.04.2018 10:46:30-11:16:30	1042.1	14.3	30.0	outdoor	764.0
13.04.2018 11:36:00-12:13:30	1064.9	15.4	37.5	outdoor	801.5
17.04.2018 11:07:00-15:53:00	1038.1	19.1	286.0	outdoor	1087.5
18.04.2018 10:42:00-15:23:00	1043.4	21.2	281.0	outdoor	1368.5
19.04.2018 11:01:00-12:12:00	1021.0	19.1	71.0	outdoor	1439.5
19.04.2018 12:45:00-16:05:30	1033.5	24.2	200.5	outdoor	1640.0
21.04.2018 11:03:00-12:18:00	1029.5	21.9	75.0	outdoor	1715.0
21.04.2018 12:46:00-13:30:30	1038.2	25.0	44.5	outdoor	1759.5
21.04.2018 13:31:30-14:43:30	1022.7	26.4	72.0	outdoor	1831.5
21.04.2018 14:44:30-15:15:30	1016.8	26.9	31.0	outdoor	1862.5
22.04.2018 11:37:30-12:25:30	1007.0	23.6	48.0	outdoor	1910.5
22.04.2018 13:31:30-14:54:00	997.6	28.2	82.5	outdoor	1993.0

Table 8: Data record of fulfilled exposure test requirements

Annex C Technical drawings and specifications

C.1 Technical Drawings

Drawing number or drawing name	Date of revision
Manifolder	03.05.2017
pipeline	03.05.2017
solarvacuumtube	01.12.2017
Solinas 3 plus kurz	01.12.2017
Solinas 3 Solinas 3 plus	07.05.2017
Heat pipe	01.12.2017
Glasstärken	10.01.2019

Table 9: Technical drawings

C.2 Specifications

Document name	Date of revision
2016-11-28 Unterlagen.pdf	28.11.2016
specs FK solinas3.xlsx	07.01.2019
Spezifikationen_div.pdf	17.01.2019

Table 10: Specifications

C.3 Bill of materials

Document name	Date of revision
FK Solinas 3 BOM.xls	07.01.2019

Table 11: Bill of materials

Annex D Material efficiency aspects

Material efficiency aspect include the use of materials, the ability to re-use components or recycle materials at end-of-life, use of re-used components and/or recycled materials, upgradeability, ability to extract key components for reuse, reparability, recycling, identifiability of the components, reusability, recyclability. (ISO 9806:2017 Annex F)

All collector materials with a total mass > 0.1 kg are listed below. Flashing kits and mounting parts are not listed.

Material	Description	Weight [kg] approx.	Identifiable Y/N	Separable Y/N	Replaceable Y/N
Aluminium	Heat-conducting metal sheet	2.3	Y	Y	Y
Aluminium	Header / Frame	7.8	Y	Y	Y
Copper	Header / Heatpipes	4.6	Y	Y	Y
Glass	Glasstubes	30.4	Y	Y	Y
PU / Rockwool	Insulation	0.4	N	N	N
Silicon	Seals	0.9	N	Y	Y
Plastic	Tubeshoes	0.8	N	Y	Y

Table 12: Collector materials

Identifiable: Is the material easily to be identified? Different metals and glass are deemed identifiable. Plastics shall be marked for identification. (e.g. SPI resin identification coding system)

Separability: Is the material at the end of life disassembly easily (that is, by simple mechanical operation using tools like screwdrivers and hammers and without using any specialized separation processes) separated from other materials such that the purity of the material is better than 95 %.

Replaceable: Parts that can be replaced by non-professionals without specific manual skills in less than 30 min using standard household tools like screwdrivers or hammers only.

The ratings in this Annex must be considered as partly subjective assessment according to best judgement of the test engineers. The findings are based on the final inspection test.

Annex E Results according ISO 9806:2013

E.1 Parameters for efficiency equation

Reference area	Absorber	Aperture	Gross	
$\eta_{0,hem}$	0.745	0.646	0.398	- - -
a_1	2.41	2.09	1.29	$Wm^{-2}K^{-1}$
a_2	0.0026	0.0023	0.0014	$Wm^{-2}K^{-2}$

Table 13: Parameters for efficiency equation

E.2 Efficiency curve for G = 800 Wm^{-2}

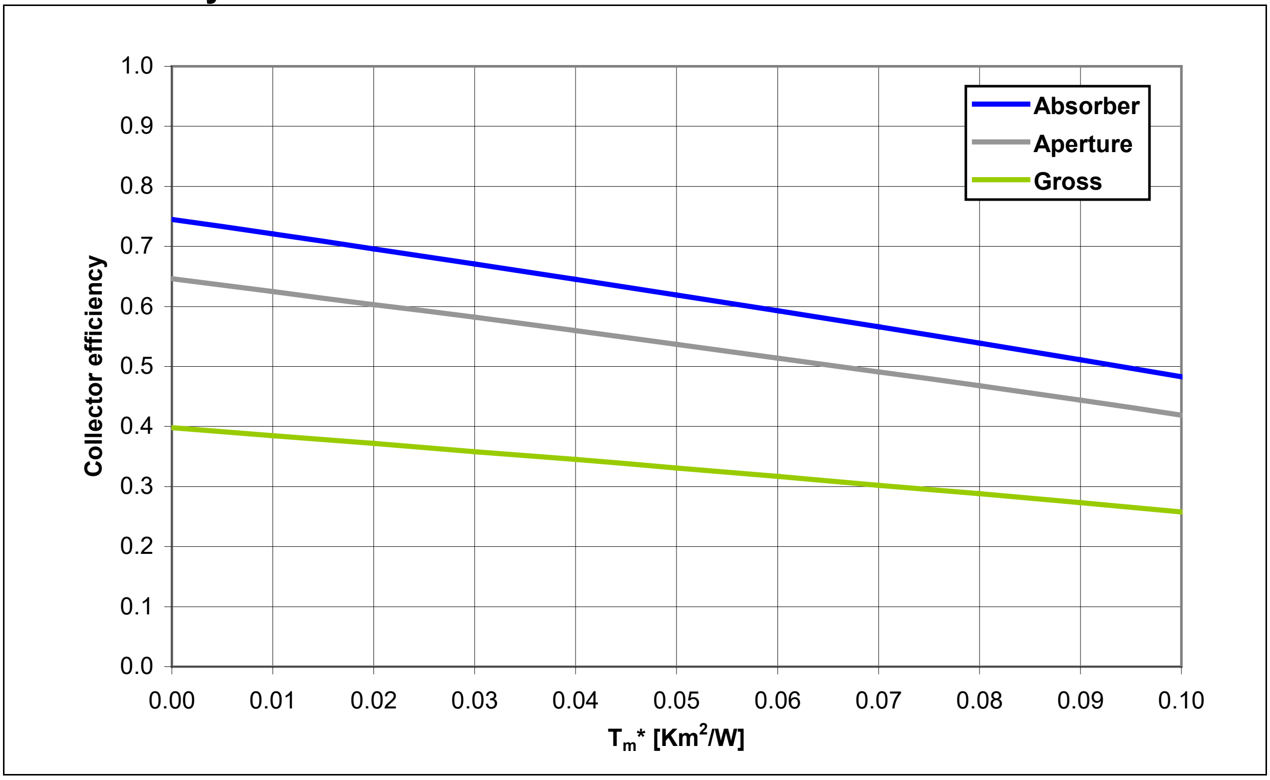


Figure 9: Collector efficiency for G=800 Wm^{-2}

E.3 Power output per collector unit

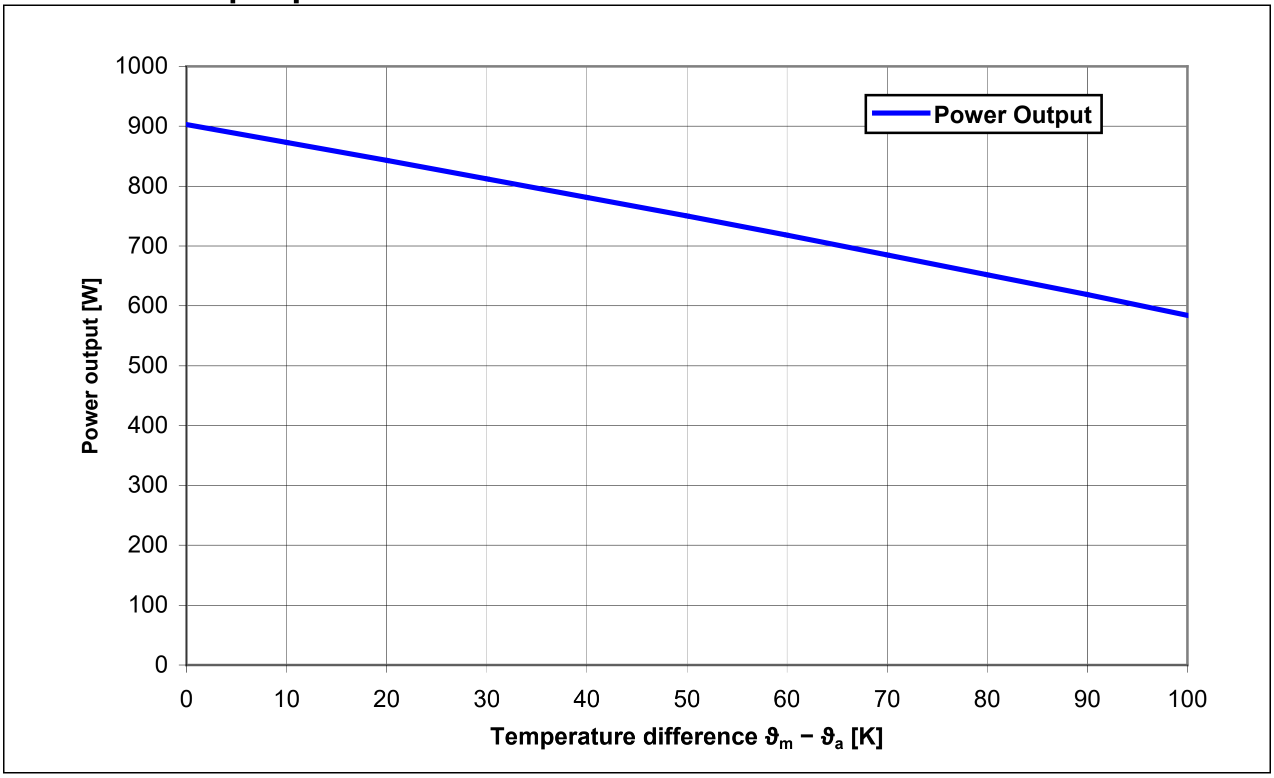


Figure 10: Power output per collector unit at G=1000 W/m²

$\vartheta_m - \vartheta_a$ [K]	**Global irradiance**		
	G = 400 Wm^{-2}	**G = 700 Wm^{-2}**	**G = 1000 Wm^{-2}**
10 K	331 W	602 W	872 W
30 K	270 W	541 W	811 W
50 K	207 W	477 W	748 W

Table 14: Table of power output per collector

Peak power 903 W

Annex F Additional information required by different regulatory frameworks

F.1 European construction Product Regulation CPR

Collector was tested according to Table 1 of EN ISO 9806:2017	Yes
None of the findings was rated as major failure according to clause 17 of EN ISO 9806:2017	Yes
Reaction to fire	NT
External fire performance	NT
Release of dangerous substances	NT
Electrical safety	NT
Sound level	NT
Snow load	1500 Pa
Wind load	1500 Pa
Weather tightness of the collector	Pass
Thermal performance (Peak power)	903 W

Classification of collectors with respect to the intended place of installation

In building	No
On building	Yes
Off building	Yes

F.2 Energy related products directive ErP

Collector reference area A_{Sol} ($A_{Sol} = A_G$)	2.27 m^2
Collector efficiency η_{Col}	34 %
Collector zero loss efficiency η_0	0.398
Collector first order coefficient a_1	1.29 $Wm^{-2}K^{-1}$
Collector incidence angle modifier IAM	1.26
Thermal output	903 W

F.3 Solar Keymark

Hydraulic designation code	1-H-12S-C:19,1260

Annex G Additional brand names

The collector is also distributed under the following brands and brand names.

- None