TÜV Rheinland Energie und Umwelt GmbH
Solar Energy

Test Report

Prüfbericht

Qualification of a Solar Collector in accordance with
Qualifizierung eines Solarkollektors nach

DIN EN 12975-1: 2006+A1:2010; DIN EN 12975-2: 2006

TÜV Report No.: 21221391_Chamber

Cologne, 8 May 2013

TÜV Rheinland Energie und Umwelt GmbH
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Report-No.: 21221391_Chamber

on

Qualification of a Solar Collector in accordance with
Qualifizierung eines Solarkollektors nach

DIN EN 12975-1: 2006+A1:2010; DIN EN 12975-2: 2006

Client: Kunde	Isocal HeizKühlsysteme GmbH Donaustraße 12 88046 Friedrichshafen Germany
TÜV Quotation No.: Angebotsnummer	435/ 1420120178
TÜV Order No.: Auftragsnummer	21221391
Order of: Datum der Beauftragung	2012-12-20
Date of Receipt of Test Item: Anlieferdatum Prüfmuster	2013-03-09
Commencement of Test: Testbeginn	2012-10-25
TÜV Client No.: Kundennummer	118470
Inspector: Prüfer	Ulrich Fritzsche
Business Field: Geschäftsfeld	Solar Energy
No of Pages: Seitenzahl	17
Appendix: Anhang	15 to 17

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1 Summary of test results
Zusammenfassung

Qualification of a Solar Collector in accordance with
Qualifizierung eines Solarkollektors nach

DIN EN 12975-1: 2006+A1:2010; DIN EN 12975-2: 2006

Manufacturer : Isocal HeizKühlsysteme GmbH
Hersteller

Donaustraße 12
88046 Friedrichshafen
Germany

Brand : isocal
Handelsname

Collector type : SLK-S
Kollektortyp

Basis of testing : DIN EN 12975-2:2006
Prüfgrundlage (adapted to no irradiance procedure)

Test	Date		Summary of main test results Zusammenfassung der Hauptergebnisse
	Start	End	
Thermal performance test without irradiation Wärmeleistung ohne Einstrahlung	2013-04-30	2013-05-07	No visual damages

All above listed tests following the standard DIN EN 12975-2:2006 were passed successfully in accordance with the criteria.
Alle oben aufgeführten Tests in Anlehnung an DIN EN 12975-2:2006 wurden entsprechend der Kriterien bestanden.

Cologne, 08 May 2013

Responsible for collector testing

Dipl.-Ing. J. Sommer

Team manager
Solar Thermal Energy

Dipl.-Ing. U. Fritzsche

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Summary of collector performance test results without irradiation:

Zusammenfassung der Ergebnisse der Leistungsprüfung ohne Einstrahlung

Manufacturer Hersteller	Isocal Heizkühlsysteme GmbH
Brand Handelsname	Isocal
Collector type Kollektortyp	SLK-S
Year of manufacture Herstellungsjahr	2013

Length Länge	2120 mm	Absorber area Absorberfläche	2.544 m²
Width Breite	1290 mm	Aperture area Aperturfläche	2.544 m²
Height Höhe	50mm	Gross area Bruttofläche	2.560 m²
Weight (empty) Gewicht (leer)	38 Kg	Mass flow Massenstrom	0.045kg/(m²s)
Heat transfer medium Prüfwärmeträger	Water	Test pressure: Prüfdruck	75 kPa

Thermal performance

Thermische Leistungsfähigkeit

	Absorber area (x_A)	Aperture area (x_a)	Unit
Conversion factor η_{0x}'' Konversionsfaktor	0.0	0.0	[ ]
Collector efficiency coefficient (wind dependence) b_{ux} Kollektorwirkungsgradfaktor (windabhängig)	0.0	0.0	$[m^{-1}s]$
Heat loss coefficient at (Tm-Ta)=0 b_{1x} Kollektorwirkungsgradfaktor (Tm-Ta)=0	26.58	26.58	$[Wm^{-2}K^{-1}]$
Wind dependence of heat loss coefficient b_{2x} Kollektorwirkungsgradfaktor	24.14	24.14	$[Wsm^{-3}K^{-1}]$

Output power per collector unit in W:

Ausgangsleistung pro Kollektormodul in W:

	Net Irradiation (G''=1) Rel. humidity = 20% (no condensation) Nettoeinstrahlung; Rel. Luftfeuchte			
$T_m - T_a$ =	-2 K	-5 K	-10 K	
u= 0.5 m/s	197	492	983	
u= 1.5 m/s	320	799	1597	
u= 3.0 m/s	504*	1259*	2519*	

*Extrapolated

2 Setting of tasks
Aufgabenstellung

A thermal performance test without irradiation following DIN EN 12975-2:2006 of the unglazed Isocal Heizkühlsysteme GmbH collector SLK-S should be performed.

Es soll eine Kollektorleistungsprüfung ohne Einstrahlung des unabgedeckten Isocal Heizkühlsysteme GmbH Kollektors SLK-S in Anlehnung an DIN EN 12975-2:2006 durchgeführt werden.

3 Basis of testing
Grundlagen

DIN EN 12975-1:2006+A1:2010 *„Thermische Solaranlagen und ihre Bauteile- Kollektoren- Teil 1: Allgemeine Anforderungen“*
DIN EN 12975-1:2006+A1:2010“ Thermal solar systems and components - Collectors - Part 1: General requirements”

DIN EN 12975-2:2006 *„Thermische Solaranlagen und ihre Bauteile- Kollektoren- Teil 2: Prüfverfahren“*
DIN EN 12975-2:2006 “Thermal solar systems and components - Collectors - Part 2: Test procedure”

The test procedure for thermal performance testing of unglazed collectors was adapted to a “no-irradiance” test below ambient temperature.

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4 Sampling
Probenahme

Prototype samples Prototyp	
Samples from pilot production Prüfmuster aus der Pilotfertigung	x
Samples from serial production Prüfmuster aus der Serienproduktion	
Selection of test samples acc. to Solar Keymark scheme rules Prüfmusterauswahl entsprechend der Solar Keymark Regeln	
Random selection of test samples acc. to SRCC scheme rules Prüfmusterauswahl entsprechend der SRCC Regeln	

5 Description of the collector construction
Beschreibung der Kollektorkonstruktion

Manufacturer Hersteller	Isocal Heizkühlsysteme GmbH
Brand name Handelsname	isocal
Collector Type Kollektortyp	SLK-S
Category Kategorie	Unglazed Collector
Date of manufacture Produktionsdatum	2013
Serial number Seriennummer	394/395
Drawing numbers Zeichnungsnummern	No information

① Determinate by test laboratory
② reviewed manufacturer information
③ according to manufacturer information

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Collector & construction:
Kollektor & Konstruktion

Gross dimensions l x w x h [mm] Bruttofläche l x b x h	2120 x 1290 x 50 ②
Absorber dimensions l x w [mm] Absorberfläche l x b x Anzahl	2212 x 1200 ①
Aperture dimensions l x w [mm] Aperturfläche l x b x Anzahl	2212 x 1200 ①
Gross/ aperture/ absorber area [m²] Brutto-/ Apertur-/ Absorberfläche	2.56 ② / 2.544 ① / 2.544 ①
Weight empty [kg] Leergewicht	2 x 19 (collector without mounting structure) ③
Fluid content [l] Flüssigkeitsinhalt	2 x 22.5 ③

Absorber:
Absorber

Construction type Bauart	PE-LD ③

Header/ connections:
Sammelleitung/ Anschlüsse

No. and dimensions of connections Anzahl und Dimension der Anschlüsse	4 ②	28 mm ②

Limit values (given by the manufacturer):
Grenzwerte

Max. operating temperature [°C] Maximale Betriebstemperatur	60 ③
Maximum pressure [kPa] Maximaler Betriebsdruck	20 ③
Heat transfer medium Wärmeträger	No information ③
Other limitations Weitere Einschränkungen	
Collector mounting Montagearten	tilted and flat roof mounting is possible ③

① Determinate by test laboratory
② reviewed manufacturer information
③ according to manufacturer information

6 Execution and evaluation
Durchführung und Auswertung

6.1 Visual inspection
Sichtprüfung

Date Datum	2013-03-09	Inspector Prüfer	Kämmer

Internal barcode no. Interne Barcode Nummer	Serial no. Seriennummer	Description of defects Beschreibung der Schäden
20130001202	395	No visual damages
20130001202	394	No visual damages

Fig. 1: Visual Incoming Inspection

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7 Measuring results of thermal performance testing;
Prüfergebnisse der Leistungsprüfung von Sonnenkollektoren

7.1 Test method following DIN EN 12975-2:2006 chapter 6.2
Prüfgrundlage in Anlehnung an DIN EN 12975-2:2006 Kapitel 6.2

○ outdoor steady state (6.2.4)
stationär, im freien

● indoor steady state (6.2.5)
stationär, indoor

Serial no. Seriennummer	394/395	
Date (Start/End) Datum (Start/Ende)	30 April 2013	04 May 2013
Inspector Prüfer	U. Fritzsche	

7.2 Test conditions
Prüfbedingungen

Latitude [°] Geographische Breite	indoor
Longitude [°] Geographische Länge	indoor
Collector tilt [° from horizontal] Kollektorneigung	(35°)
Collector azimuth [° from south] Kollektorazimut	indoor
Orientation of absorber or pipes Ausrichtung des Absorbers oder der Absorberröhren	vertical
Mass flow [kg/(m²s)] Massenstrom	0.045
Aperture area A_a [m²] Aperturfläche	2.544

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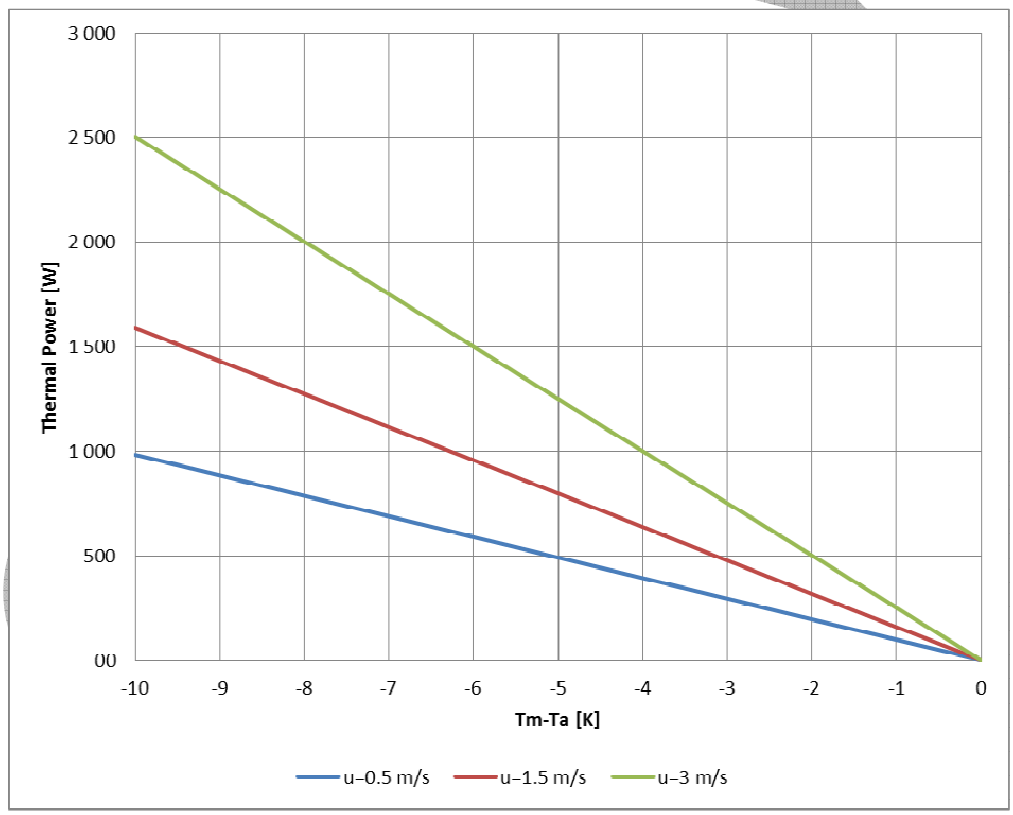
7.2.1 Test results thermal performance including wind dependency without irradiation
Prüfergebnisse windgeschwindigkeitsabhängige Wärmeleistung ohne Einstrahlung

First order fit to data
Ausgleichskurve 1. Ordnung für die Messwerte

$$\dot{Q} = A \cdot G'' \left(\eta_0 (1 - b_u u) - (b_1 + b_2 u) \frac{(t_m - t_a)}{G''} \right)$$

Conversion factor η_{0a}" Konversionsfaktor	0.0 (based on aperture area)
Collector efficiency coefficient (wind dependence) b_{ua} Kollektorwirkungsgradfaktor (windabhängig)	0.0 (based on aperture area)
Heat loss coefficient at (Tm-Ta)=0 b_{1a} Kollektorwirkungsgradfaktor (Tm-Ta)=0	26.58(based on aperture area)
Wind dependence of heat loss coefficient b_{2a} Kollektorwirkungsgradfaktor	24.14 (based on aperture area)

Power curve *per collector unit (for G" = 1 W/m², 20 % rel. humidity)*
Leistungskurve *pro Kollektormodul*



Maximum power [W_{peak}] (G"=1 W/m² u=??) **Spitzenleistung** per collector unit/ pro Kollektormodul	**Not jet defined!**
Details of any damage and problems: Einzelheiten hinsichtlich vorhandener Fehler.	
The condensation effect is not covered by the above mentioned results.	

For more details about thermal performance test see annex 2.

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8 General remarks

Bemerkungen

All results only refer to the test samples that were subjected to testing.

The extended total measuring uncertainty (k=2) for the indoor performance figures is:

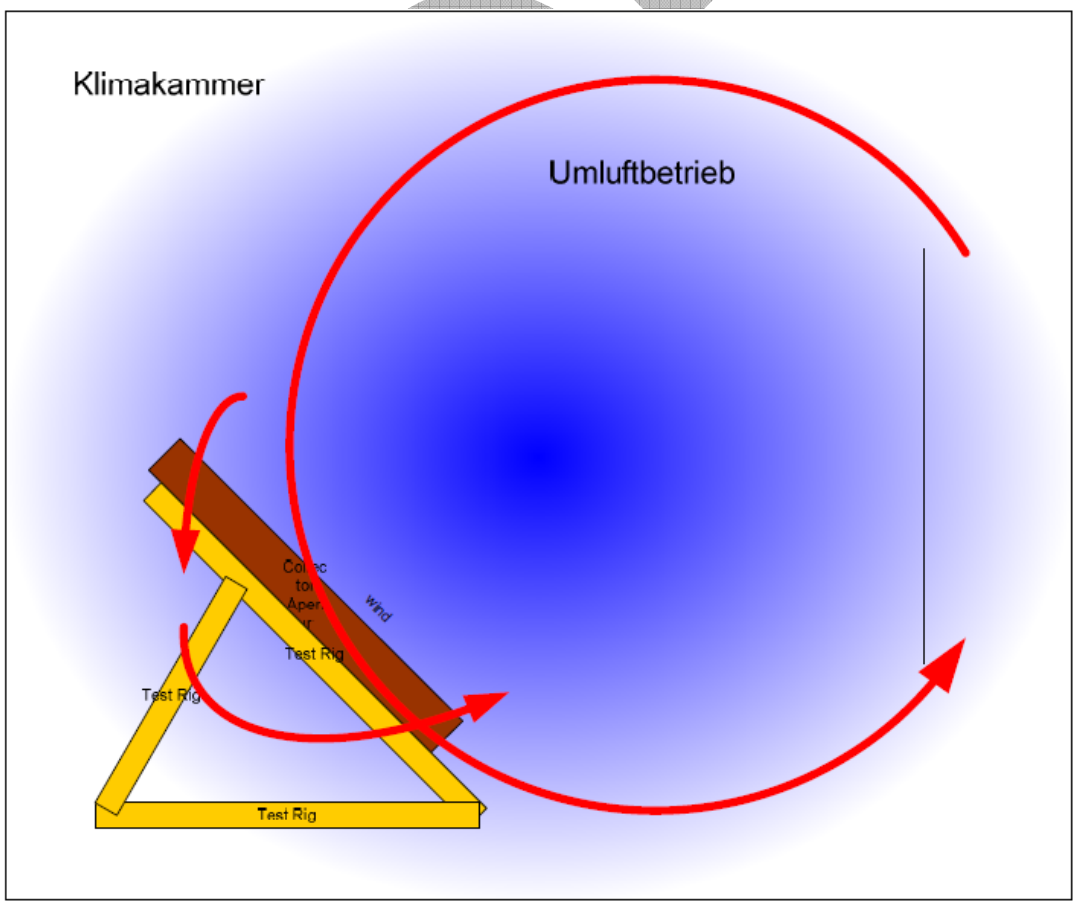
$U(P) \leq \pm 2.0\ \%$

For description of the thermal performance without irradiance, there's no general equation available so far. The Equation for unglazed collectors could also be used for no irradiation measurement with a second set of parameter.

But even then, the condensation effect will not be covered by that equation.

The measured values could be taken out of Table 2, Appendix 2.

Test Set-Up:



Determination of condensation effects:

The no-irradiance thermal performance detection was performed with low relative humidity (20%, without condensation) as well as with high relative humidity (90%, with condensation) at an ambient temperature of 40°C. This temperature level was used because of the limited minimum fluid temperature (around 16°C) as well as the difficulty in controlling the humidity related to the absolute water content per m².

The three wind speed ranges (0.6; 1.1; 1.4 m/s) were used for both humidity level.

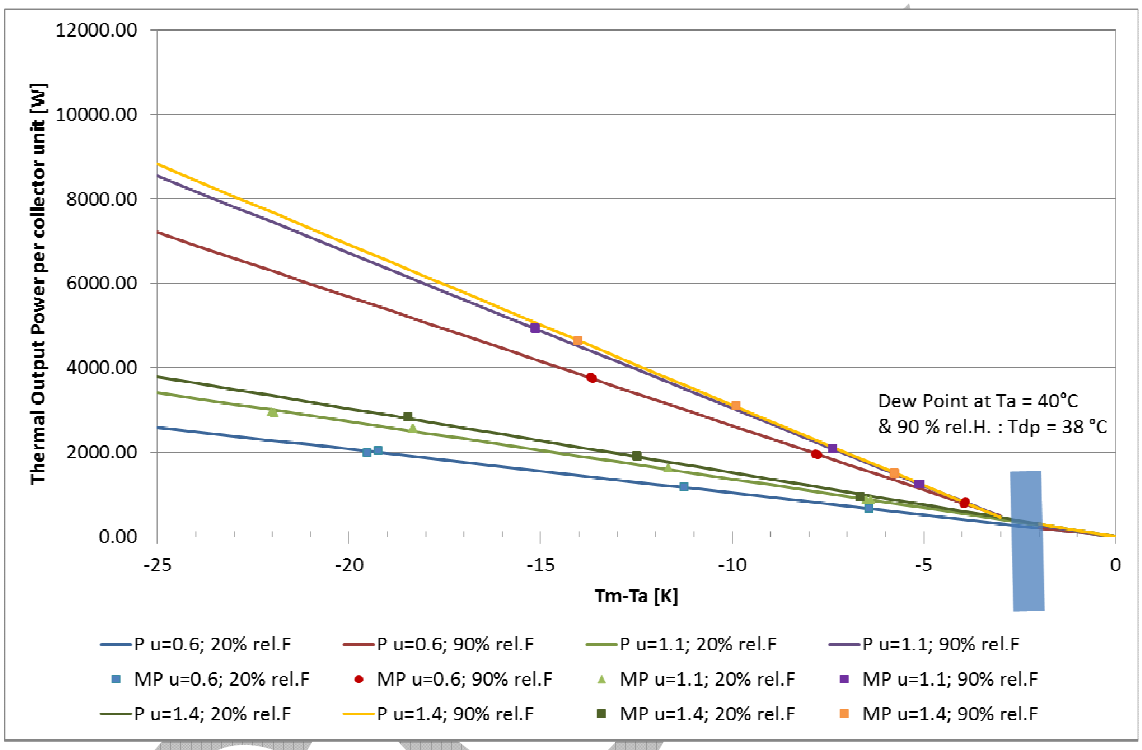


Fig. 2: Power curve at 0 W/m² net irradiance with and without condensation

The wind speed dependency is similar for dry and condensation mode. To take the condensation effect into account, a more detailed model taking the dew point and the second inclination value into account needs to be developed.

Comparison with results determined under the sun simulator (Report 21220633):

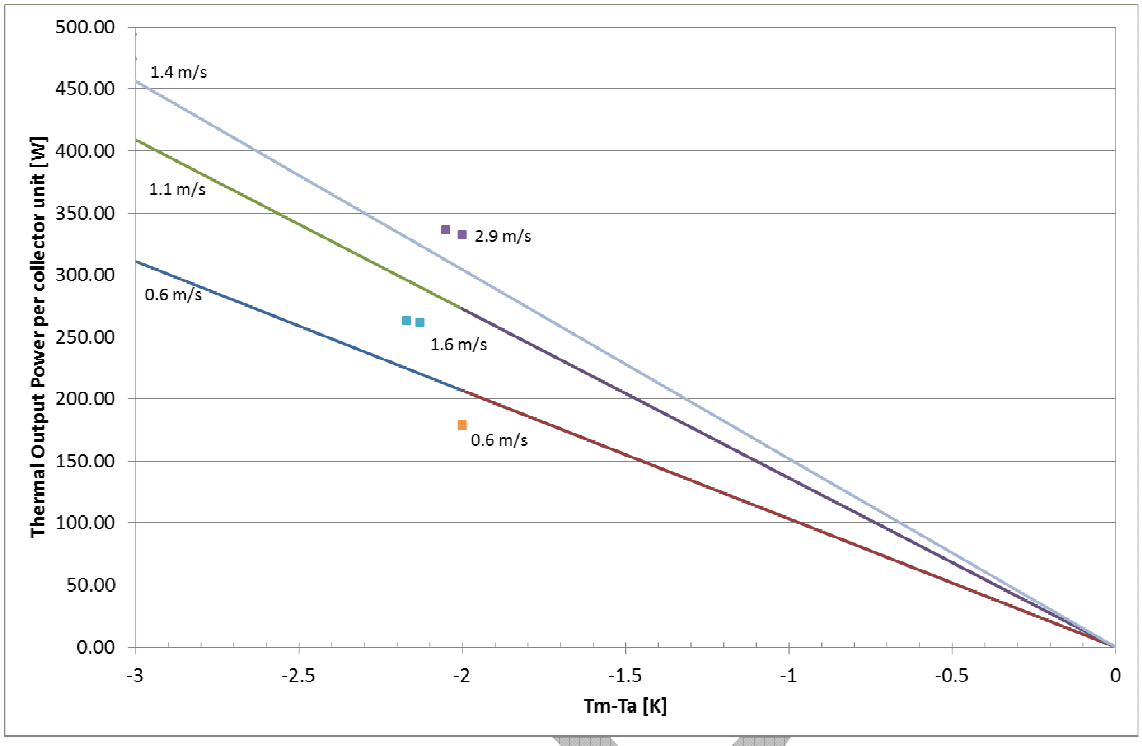


Fig. 3: Power curve at 0 W/m² net irradiance (comparison with last test sequence)

The performance values detected under the sun simulator (Report 21220633) showed a reasonable fit with the new test results. As the collector under the sun simulator was only ventilated parallel to its aperture area, the second (back-side) absorber was not perfectly reached by the flow.

With the new test procedure, the collector will now be passed completely by the flow and the performance is better.

But as there's only a one point velocity measurement in the middle of the collector (see Fig.: 6), the uncertainty related to the mean wind speed determination is still high.

Table of Revision

No	Report/ Revision no.:	Date	Modification Description
1			
2			

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Appendix 1: Nomenclature

Symbol	Meaning	Units
a_1	Algebraic constant, reference to Ti*	$Wm^{-2}K^{-1}$
a_2	Algebraic constant, reference to T_i^*	$Wm^{-2}K^{-2}$
A_A	Absorber area of collector	m^2
A_a	Aperture area of collector	m^2
A_G	Gross area of collector	m^2
D	Date	MM/DD/YYYY
c_f	Specific heat capacity of heat transfer fluid	$Jkg^{-1}K^{-1}$
C	Effective thermal capacity of collector	JK^{-1}
$G^{1)}$	Total solar irradiance	Wm^{-2}
G''	net irradiance	Wm^{-2}
G_b	Direct solar irradiance (beam irradiance)	Wm^{-2}
E_L	Longwave irradiance (λ > 3µm)	Wm^{-2}
LT	Local time	h
K_ϑ	Incident angle modifer	-
$\dot{m}$	Mass flowrate of heat transfer fluid	kgs^{-1}
$\dot{Q}$	Useful power extracted from collector	W
t	time	s
t_a	Ambient or surrounding air temperature	°C
t_e	Collector outlet (exit) temperature	°C
t_i	Collector inlet temperature	°C
t_m	Mean temperature of heat transfer fluid	°C
T_i^*	Reduced inlet temperature diffeence	m^2KW^{-1}
T_m^*	Reduced mean temperature difference	m^2KW^{-1}
T_s	Atmospheric or equivalent sky radiation temperature	K
U	Measured overall heat loss coefficient of collector with reference to Ti*	$Wm^{-2}K^{-1}$
$\overline{U}$	Measured overall heat loss coefficient of collector, with reference to Tm*	$Wm^{-2}K^{-1}$
U_L	Overall heat loss coefficient of a collector with uniform absorber temperature tm	$Wm^{-2}K^{-1}$
u	Surrounding air speed	ms^{-1}
V_f	Fluid capacity of the collector	m^3
Δp	Pressure difference between fluid inlet and outlet	Pa
Δt	Time interval	s
τ_c	Collector time costant	s
τ	Transmittance	-
$(\tau\alpha)_{en}$	Product of effective transmittance x absorptance for direct solar radiation at normal incidence	-
η_G	Thermal efficiency of collector (gross)	-
η_a	Thermal efficiency of collector (aperture)	-
η_0	Zero loss thermal efficiency	-

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Appendix 2: Thermal performance test results

Table 2.1: Evaluation of unglazed steady state collector test without irradiation performed within climate chamber with varying wind speed and rel. humidity.

Datum	Uhrzeit	u_wind	tamb1	t_amb	c_f	roh_11	G"	t_in_11	t_out_11	Vdot_MID_	mdot_11	rel. Humidity	Tdp	Abs. Humidtm	tm-ta	Q
30.04.2013	10:43:11	0.6	40.06	40.46	4.18356	992.32	1	15.65	26.00	170.7	0.04705	20	12.8	10.2	20.82	-19.24	2036.9
30.04.2013	10:53:11	0.6	40.17	40.56	4.18365	992.27	1	15.63	25.67	170.6	0.04702	20	12.8	10.2	20.65	-19.52	1973.9
30.04.2013	12:26:41	0.6	40.81	41.02	4.1817	992.02	1	26.50	32.61	165.7	0.04565	20	12.8	10.2	29.56	-11.25	1166.5
30.04.2013	12:36:41	0.6	40.82	41.04	4.1817	992.02	1	26.50	32.65	165.8	0.04568	20	12.8	10.2	29.57	-11.25	1174.4
30.04.2013	14:01:12	0.6	40.43	40.69	4.18201	992.17	1	32.23	35.76	163.1	0.04496	20	12.8	10.2	34.00	-6.44	664.3
30.04.2013	14:11:12	0.6	40.43	40.70	4.18201	992.17	1	32.22	35.78	163.0	0.04491	20	12.8	10.2	34.00	-6.43	668.7
02.05.2013	08:50:25	0.6	40.44	40.76	4.18188	992.17	1	22.84	30.65	418.6	0.11537	90	38	45.9	26.75	-13.69	3768.4
02.05.2013	09:00:25	0.6	40.38	40.69	4.18188	992.19	1	22.86	30.62	418.3	0.11528	90	38	45.9	26.74	-13.64	3742.4
02.05.2013	09:39:25	0.6	40.26	40.58	4.18183	992.24	1	30.42	34.47	417.8	0.11514	90	38	45.9	32.44	-7.82	1949.8
02.05.2013	09:59:26	0.6	40.25	40.58	4.18183	992.24	1	30.49	34.48	417.8	0.11514	90	38	45.9	32.49	-7.77	1921.3
02.05.2013	10:26:26	0.6	40.13	40.44	4.18237	992.29	1	35.37	37.07	417.6	0.11511	90	38	45.9	36.22	-3.91	815.3
02.05.2013	10:36:25	0.6	40.11	40.43	4.18236	992.29	1	35.37	36.96	417.5	0.11509	90	38	45.9	36.17	-3.95	763.4
30.04.2013	18:13:27	1.1	40.11	40.47	4.18197	992.29	1	32.82	34.64	419.9	0.11573	20	12.8	10.2	33.73	-6.38	877.9
30.04.2013	18:33:27	1.1	40.19	40.50	4.18197	992.26	1	32.78	34.58	419.7	0.11569	20	12.8	10.2	33.68	-6.51	871.3
30.04.2013	20:31:41	1.1	40.00	40.20	4.18514	992.34	1	14.98	21.10	414.2	0.11416	20	12.8	10.2	18.04	-21.95	2924.1
30.04.2013	20:41:45	1.1	40.00	40.21	4.18519	992.34	1	14.89	21.07	414.2	0.11416	20	12.8	10.2	17.98	-22.02	2952.1
30.04.2013	22:18:45	1.1	40.33	40.65	4.18172	992.21	1	26.99	30.33	420.6	0.11593	20	12.8	10.2	28.66	-11.67	1619.9
30.04.2013	22:28:45	1.1	40.29	40.62	4.18172	992.22	1	26.98	30.31	420.8	0.11599	20	12.8	10.2	28.64	-11.65	1618.1
01.05.2013	13:09:18	1.1	40.48	40.87	4.183	992.15	1	19.51	24.81	417.8	0.11514	20	12.8	10.2	22.16	-18.32	2554.8
01.05.2013	13:19:18	1.1	40.49	40.85	4.18301	992.15	1	19.48	24.81	417.8	0.11515	20	12.8	10.2	22.15	-18.35	2563.7
01.05.2013	17:38:20	1.1	40.15	40.54	4.18217	992.28	1	19.86	30.14	416.3	0.11476	90	38	45.9	25.00	-15.15	4933.7
01.05.2013	17:48:20	1.1	40.14	40.52	4.18217	992.28	1	19.88	30.14	416.2	0.11473	90	38	45.9	25.01	-15.13	4921.3
02.05.2013	03:12:24	1.1	40.01	40.31	4.18214	992.33	1	33.63	36.21	419.7	0.11569	90	38	45.9	34.92	-5.09	1245.0
02.05.2013	03:22:24	1.1	40.05	40.35	4.18215	992.32	1	33.63	36.21	419.8	0.11571	90	38	45.9	34.92	-5.13	1247.7
02.05.2013	07:39:25	1.1	40.03	40.39	4.18185	992.33	1	30.49	34.81	419.1	0.11553	90	38	45.9	32.65	-7.38	2084.8
02.05.2013	07:49:25	1.1	40.03	40.40	4.18185	992.33	1	30.51	34.81	419.3	0.11559	90	38	45.9	32.66	-7.37	2080.7
06.05.2013	13:49:37	1.4	40.135	40.473	4.18197	992.29	1	21.276	30.95	415.85	0.11462	90	38	45.9	26.113	-14.022	4637
06.05.2013	13:59:37	1.4	40.128	40.481	4.18197	992.29	1	21.268	30.949	415.78	0.1146	90	38	45.9	26.1085	-14.0195	4640.02
06.05.2013	15:12:07	1.4	40.067	40.422	4.18171	992.31	1	26.986	33.352	420.86	0.11601	90	38	45.9	30.169	-9.898	3088.2
06.05.2013	15:22:07	1.4	40.059	40.424	4.18171	992.31	1	26.993	33.352	421.11	0.11608	90	38	45.9	30.1725	-9.8865	3086.31
06.05.2013	15:46:38	1.4	40.02	40.38	4.18205	992.33	1	32.72	35.82	418.8	0.11543	90	38	45.9	34.2695	-5.7505	1495.4
06.05.2013	15:56:38	1.4	40.00	40.35	4.18204	992.34	1	32.69	35.80	418.7	0.11542	90	38	45.9	34.244	-5.76	1499.08
06.05.2013	17:34:48	1.4	40.24	40.57	4.18194	992.24	1	32.55	34.40	418.9	0.11545	20	12.8	10.2	33.4775	-6.7605	893.73
06.05.2013	17:44:48	1.4	40.20	40.53	4.18195	992.26	1	32.56	34.52	418.8	0.11542	20	12.8	10.2	33.538	-6.665	944.33
07.05.2013	07:33:20	1.4	40.33	40.67	4.18177	992.21	1	25.85	29.82	418.1	0.11523	20	12.8	10.2	27.8335	-12.4915	1909.55
07.05.2013	07:43:20	1.4	40.32	40.65	4.18177	992.21	1	25.88	29.81	418.1	0.11524	20	12.8	10.2	27.848	-12.469	1895.26
07.05.2013	09:12:21	1.4	40.46	40.82	4.18305	992.16	1	19.10	24.99	415.8	0.11461	20	12.8	10.2	22.0435	-18.4115	2823.08
07.05.2013	09:22:21	1.4	40.49	40.85	4.18305	992.15	1	19.10	24.98	416.0	0.11466	20	12.8	10.2	22.0385	-18.4535	2821.72

TÜVRheinland®
Precisely Right.

Appendix 3: Photo documentation

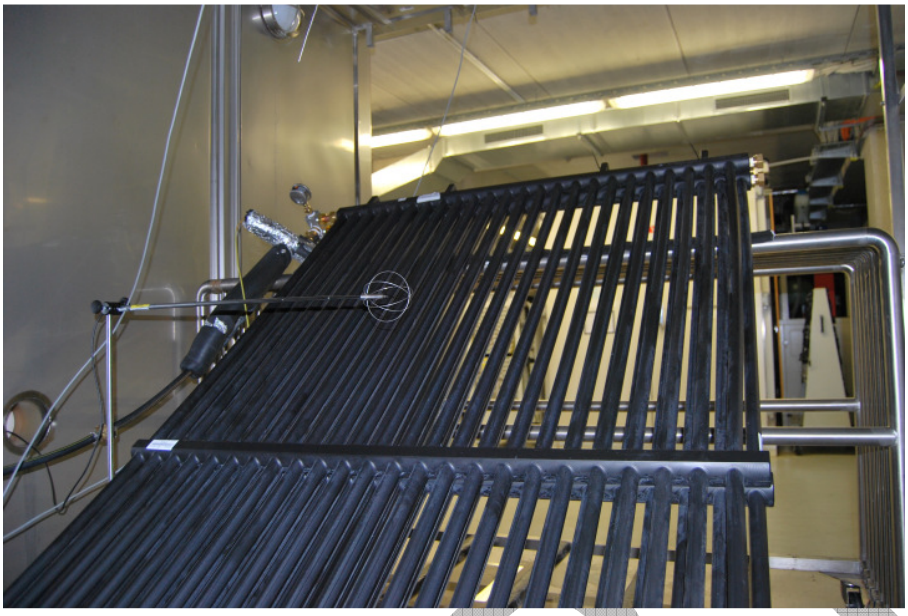

Fig. 4: performance test

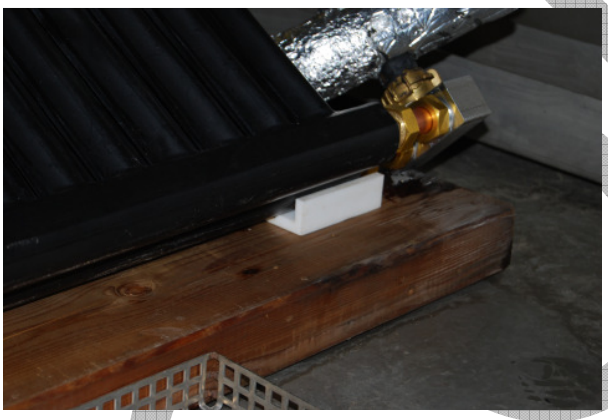

Fig. 5: collector mounting

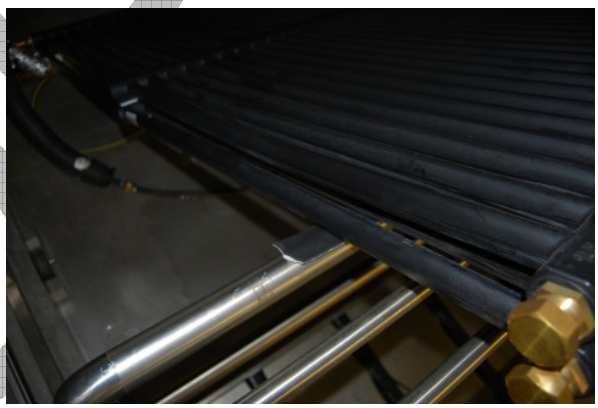

Fig. 6: collector mounting

Fig. 7: climate chamber

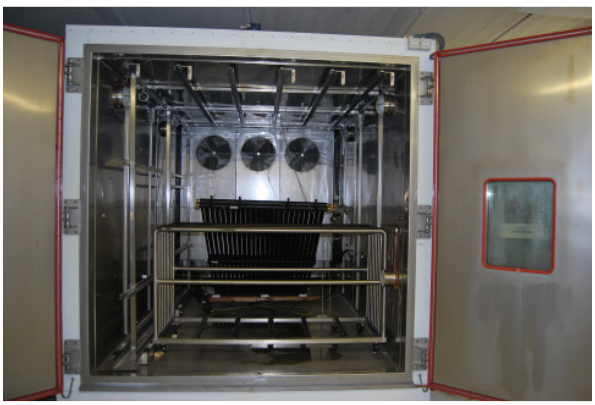

Fig. 8: climate chamber mounting