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; DIN EN 12975-2: 2006

TÜV Report No.: 212200633_P

Cologne, 12 December 2012

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-11120-01-01

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Report-No.: 212200633_P

on

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

DIN EN 12975-1: 2006; DIN EN 12975-2: 2006

Client: Kunde	Isocal HeizKühlsysteme GmbH Donaustraße 12 88046 Friedrichshafen Germany
TÜV Quotation No.: Angebotsnummer	435/ 1420120126
TÜV Order No.: Auftragsnummer	21220217
Order of: Datum der Beauftragung	2012-09-11
Date of Receipt of Test Item: Anlieferdatum Prüfmuster	2012-09-27
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	19
Appendix: Anhang	15 to 19

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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; 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

Test	Date		Summary of main test results Zusammenfassung der Hauptergebnisse
	Start	End	
Thermal performance Wärmeleistung	2012-10-25	2012-10-28	No visual damages

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

Cologne, 12 December 2012

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:
Zusammenfassung der Ergebnisse der Leistungsprüfung

Manufacturer Hersteller	Isocal Heizkühlsysteme GmbH
Brand Handelsname	Isocal
Collector type Kollektortyp	SLK-S
Year of manufacture Herstellungsjahr	2012

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	0.014 kg/(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	0.702	0.702	[ ]
Collector efficiency coefficient (wind dependence) b_{ux} Kollektorwirkungsgradfaktor (windabhängig)	0.066	0.066	$[m^{-1}s]$
Heat loss coefficient at (Tm-Ta)=0 b_{1x} Kollektorwirkungsgradfaktor (Tm-Ta)=0	32.64	32.64	$[Wm^{-2}K^{-1}]$
Wind dependence of heat loss coefficient b_{2x} Kollektorwirkungsgradfaktor	3.59	3.59	$[Wsm^{-3}K^{-1}]$

Output power per collector unit in W:
Ausgangsleistung pro Kollektormodul in W:

	Net Irradiation (G") Nettoeinstrahlung			
$T_m - T_a = 2$ K	400 W/m²	700 W/m²	1000 W/m²	
u= 0.5 m/s	515.5	1033.5	1551.6	
u= 1.5 m/s	449.8	932.2	1414.7	
u= 3.0 m/s	351.2	780.3	1209.4	

(at normal incidence angle
(bei senkrechter Einstrahlung)

2 Setting of tasks
Aufgabenstellung

A thermal performance test in accordance with DIN EN 12975-2:2006 of the unglazed Isocal Heizkühlsysteme GmbH collector SLK-S should be performed.

Es soll eine Kollektorleistungsprüfung des unabgedeckten Isocal Heizkühlsysteme GmbH Kollektors SLK-S entsprechend DIN EN 12975-2:2006 durchgeführt werden.

3 Basis of testing
Grundlagen

DIN EN 12975-1:2006 *„Thermische Solaranlagen und ihre Bauteile- Kollektoren- Teil 1: Allgemeine Anforderungen“*
DIN EN 12975-1:2006 “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”

Solar Keymark – Specific Scheme Rules: *“Specific CEN Keymark Scheme Rules for Solar Thermal Products”*

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4 Sampling
Probenahme

Prototype samples Prototyp	
Samples from pilot production Prüfmuster aus der Pilotfertigung	
Samples from serial production Prüfmuster aus der Serienproduktion	X
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	2012
Serial number Seriennummer	01409/ 01410
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	2012-09-27	Inspector Prüfer	Kämmer

Internal barcode no. Interne Barcode Nummer	Serial no. Seriennummer	Description of defects Beschreibung der Schäden
20120006327	01409	No visual damages
20120006328	01410	No visual damages

Fig. 1: Visual Incoming Inspection

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

7.1 Pressure drop test
Druckverlustprüfung

Serial no. Seriennummer	01409/ 01410
Date Datum	19 November 2012
Inspector Prüfer	Fritzsche

7.1.1 Test conditions
Prüfbedingungen

Fluid used to pressurize collector Genutztes Fluid zur Druckverlustbestimmung	Water
Average fluid temperature [°C] mittlere Fluidtemperatur [°C]	14 °C

7.1.2 Test results
Prüfergebnisse

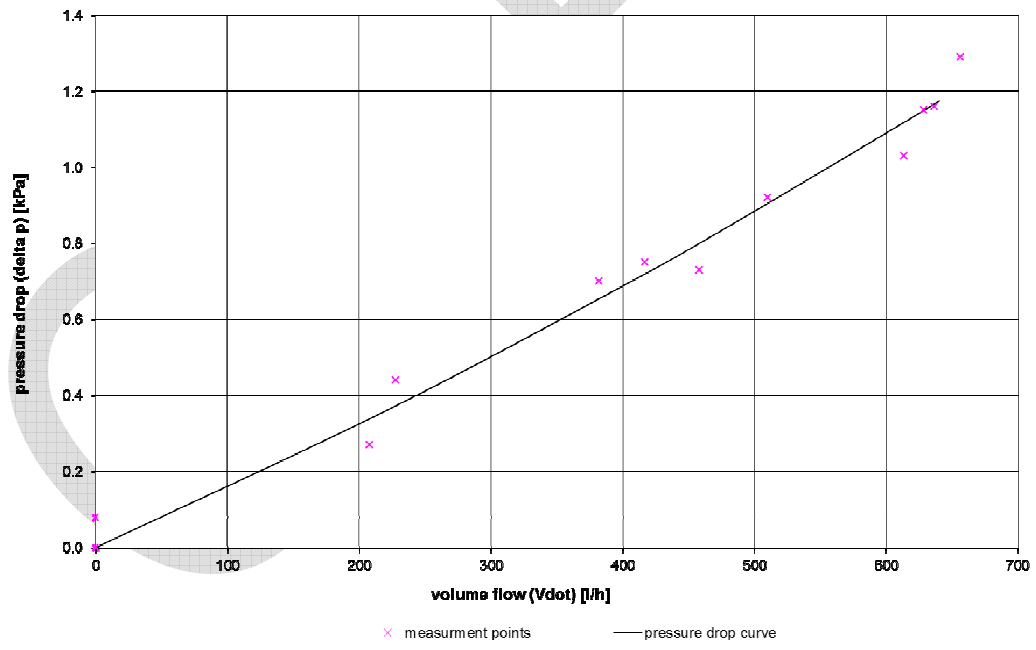


Figure 2: pressure drop curve

Function of pressure drop curve Funktion zur Bestimmung der Druckverlustkurve	$\Delta p(\dot{V})=4.801E\text{-}07 * \dot{V}^2 + 1.529E\text{-}03 * \dot{V}$

7.2 Test method according to DIN EN 12975-2:2006 chapter 6.2

Prüfgrundlage entsprechend 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	01409/ 01410	
Date (Start/End) Datum (Start/Ende)	25. October 2012	28. October 2012
Inspector Prüfer	U. Fritzsche	

7.3 Test conditions

Prüfbedingungen

Latitude [°] Geographische Breite	indoor
Longitude [°] Geographische Länge	indoor
Collector tilt [° from horizontal] Kollektorneigung	(45°)
Collector azimuth [° from south] Kollektorazimut	indoor
Orientation of absorber or pipes Ausrichtung des Absorbers oder der Absorberröhren	vertical
Mass flow [kg/(m²s)] Massenstrom	0.014
Aperture area A_a [m²] Aperturfläche	2.544

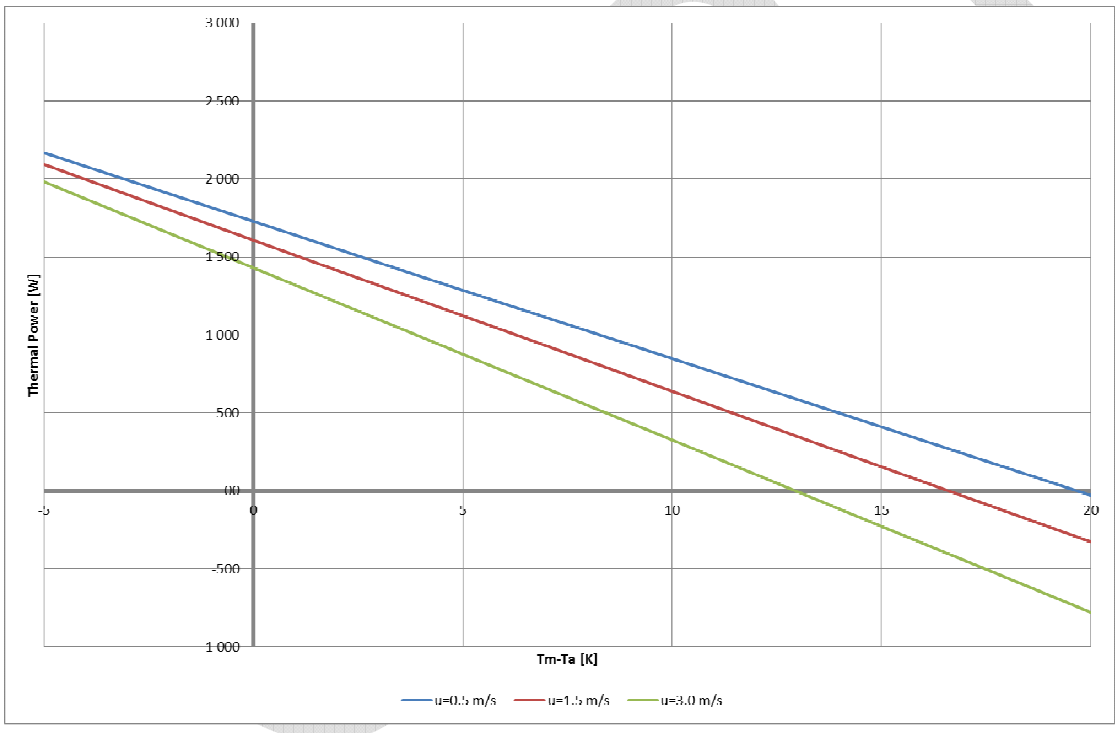
7.3.1 Test results thermal performance
Prüfergebnisse Wärmeleistung

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	0.702 (based on aperture area)
Collector efficiency coefficient (wind dependence) b_{ua} Kollektorwirkungsgradfaktor (windabhängig)	0.066 (based on aperture area)
Heat loss coefficient at (Tm-Ta)=0 b_{1a} Kollektorwirkungsgradfaktor (Tm-Ta)=0	32.64(based on aperture area)
Wind dependence of heat loss coefficient b_{2a} Kollektorwirkungsgradfaktor	3.59 (based on aperture area)

Power curve *per collector unit (for G" = 1000 W/m²)*
Leistungskurve *pro Kollektormodul*



Maximum power [W_{peak}] (G"=1000 W/m² u=0) **Spitzenleistung** per collector unit/ pro Kollektormodul	**1786**

Details of any damage and problems: Einzelheiten hinsichtlich vorhandener Fehler.
No visual damages

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 test is:

$\eta \leq \pm 2.0$ %

The sun simulator is working with an artificial cold sky to minimize long wave irradiation through the lamps. The resulting long wave irradiation for this test was L_d = + 41.4 W/m².

The resulting value G''(Net-Irradiation) was G''= $G_{mean} + L_d$ = 899 + 41.4 = 940.4 W/m².

The artificial wind generator is simulating a wind flow only parallel to aperture area.

The homogeneity of irradiance in collector plane is always better ± 5 %.

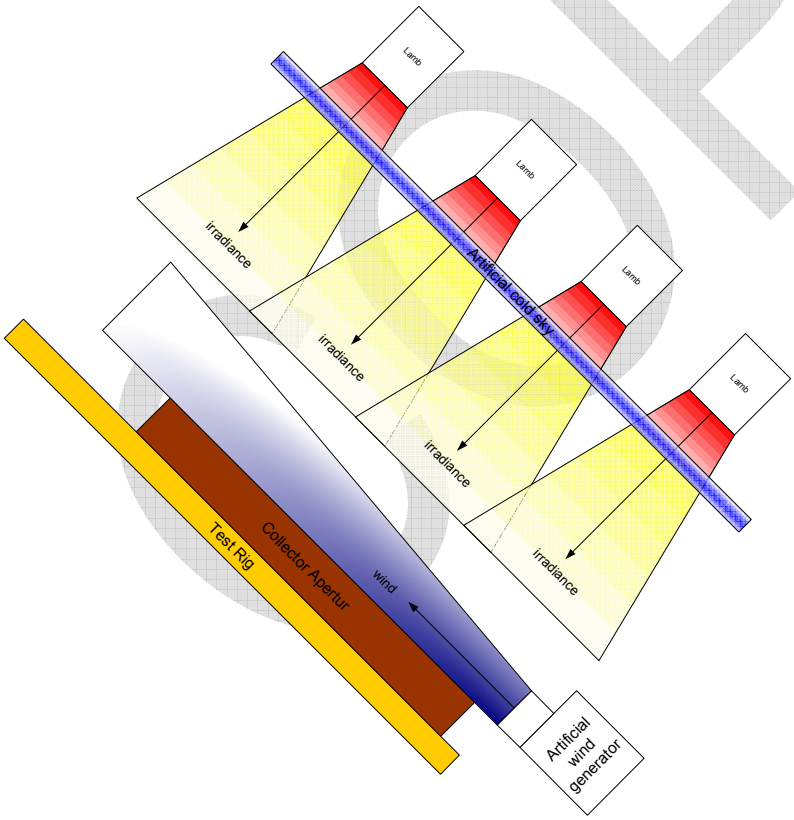

Fig. 2: Working principle of TÜV Sun Simulator

To determine the performance just related to ambient air and wind velocity, the performance at net-irradiance G''=0W/m² was detected. Because of the test set up, negative temperature differences above 2.5 K won't be possible to achieve.

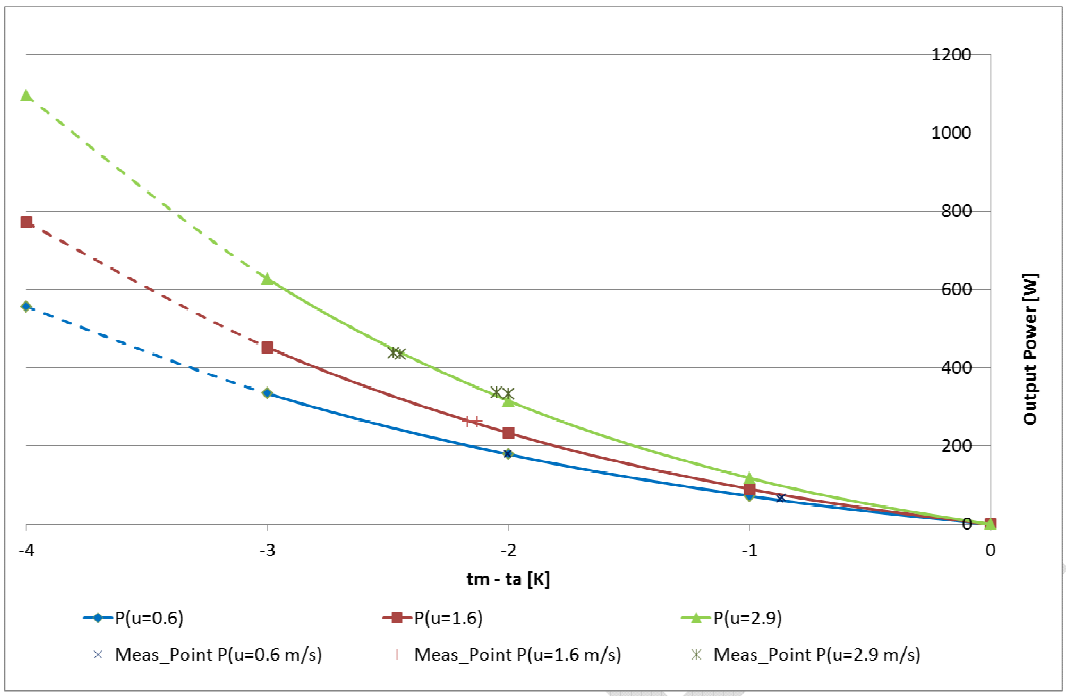

Fig. 3: Power curve at 0 W/m² net irradiance

For description of the thermal performance without irradiance, there's no general equation available so far. The measured values could be taken out of Table 2, Appendix 2.

Table of Revision

No	Report/ Revision no.:	Date	Modification Description
0	21220633_P_Report	26 November 2012	Initial report
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 steady state collector test based on aperture area and mean temperature of heat transfer fluid (multi linear regression)

	Performance results, measured and derived data												
Date	UTC	G''	G/G_d	EL	t_a	U	$\dot{m}$	t_{in}	t_m	t_m-t_a	T^*m	$\dot{Q}$	η_a
YYYY-MM-DD	hh:mm	W/m²	%	W/m²	°C	m/s	kg/s	°C	°C	K	m²K/W	W	%
2012-09-25	17:28:42	940.		41.4	24.0	0.6	0.0353	18.45	24.01	0.03	0.0000	1640.3	0.686
2012-09-25	17:43:43	940.4		41.4	24.3	0.6	0.0353	18.45	24.05	-0.30	-0.0003	1655.8	0.692
2012-09-25	19:23:43	940.4		41.4	24.6	0.6	0.0351	38.24	39.07	14.51	0.0154	242.1	0.101
2012-09-25	19:38:43	940.4		41.4	24.7	0.6	0.0351	38.25	39.07	14.40	0.0153	241.3	0.101
2012-09-25	21:16:13	940.4		41.4	25.0	0.6	0.0350	56.05	53.13	28.10	0.0299	-855.5	-0.358
2012-09-25	21:31:14	940.4		41.4	25.1	0.6	0.0350	56.09	53.19	28.06	0.0298	-849.6	-0.355
2012-09-25	22:46:14	940.4		41.4	24.6	1.4	0.0350	55.99	52.39	27.84	0.0296	-1057.1	-0.442
2012-09-25	23:01:14	940.4		41.4	24.6	1.4	0.0350	55.99	52.37	27.77	0.0295	-1062.3	-0.444
2012-09-26	00:08:44	940.4		41.4	24.5	1.4	0.0351	38.24	38.54	14.02	0.0149	90.3	0.038
2012-09-26	00:23:44	940.4		41.4	24.3	1.4	0.0351	38.24	38.56	14.25	0.0152	95.0	0.040
2012-09-26	03:17:15	940.4		41.4	23.9	1.4	0.0356	18.55	23.95	0.09	0.0001	1605.3	0.671
2012-09-26	03:32:15	940.4		41.4	24.3	1.4	0.0355	18.55	23.94	-0.34	-0.0004	1603.5	0.670
2012-09-26	08:32:15	940.4		41.4	23.5	2.9	0.0355	18.59	23.42	-0.06	-0.0001	1436.1	0.600
2012-09-26	08:47:15	940.4		41.4	24.0	2.9	0.0355	18.59	23.41	-0.60	-0.0006	1430.8	0.598
2012-09-26	10:23:16	940.4		41.4	23.9	2.9	0.0352	38.21	37.47	13.56	0.0144	-217.4	-0.091
2012-09-26	10:38:16	940.4		41.4	24.3	2.9	0.0351	38.23	37.52	13.21	0.0140	-207.8	-0.087
2012-09-26	11:17:16	940.4		41.4	24.2	2.9	0.0350	55.87	50.58	26.43	0.0281	-1550.6	-0.648
2012-09-26	11:32:16	940.4		41.4	24.4	2.9	0.0350	55.91	50.91	26.56	0.0282	-1467.0	-0.613

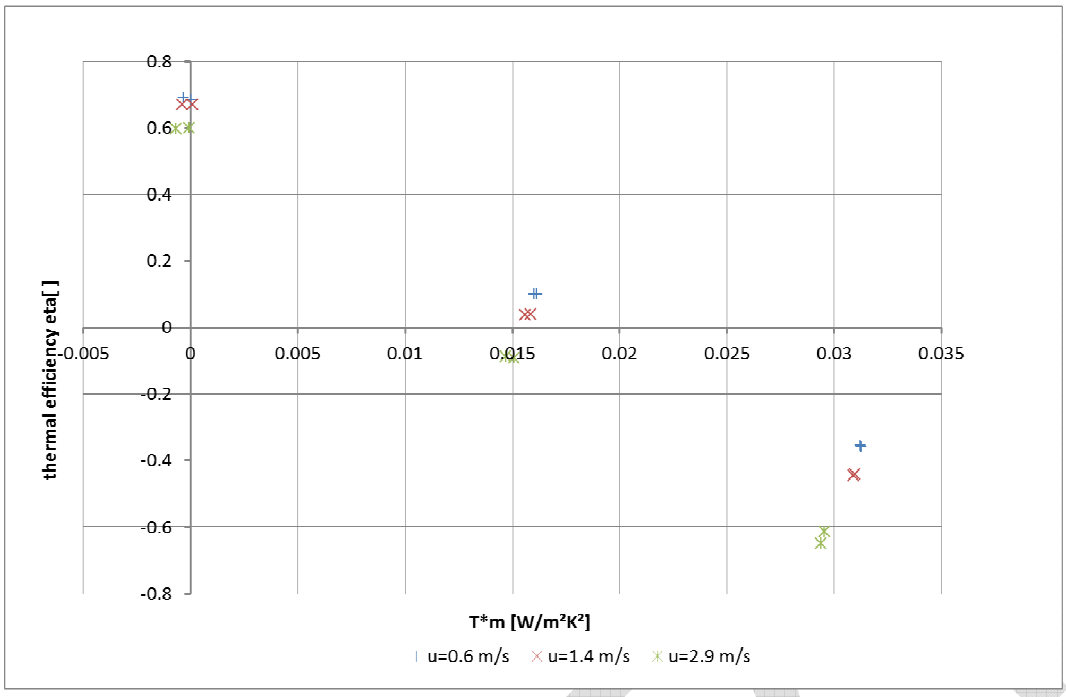

Fig. 4: Measured efficiency points at G"=940 W/m²

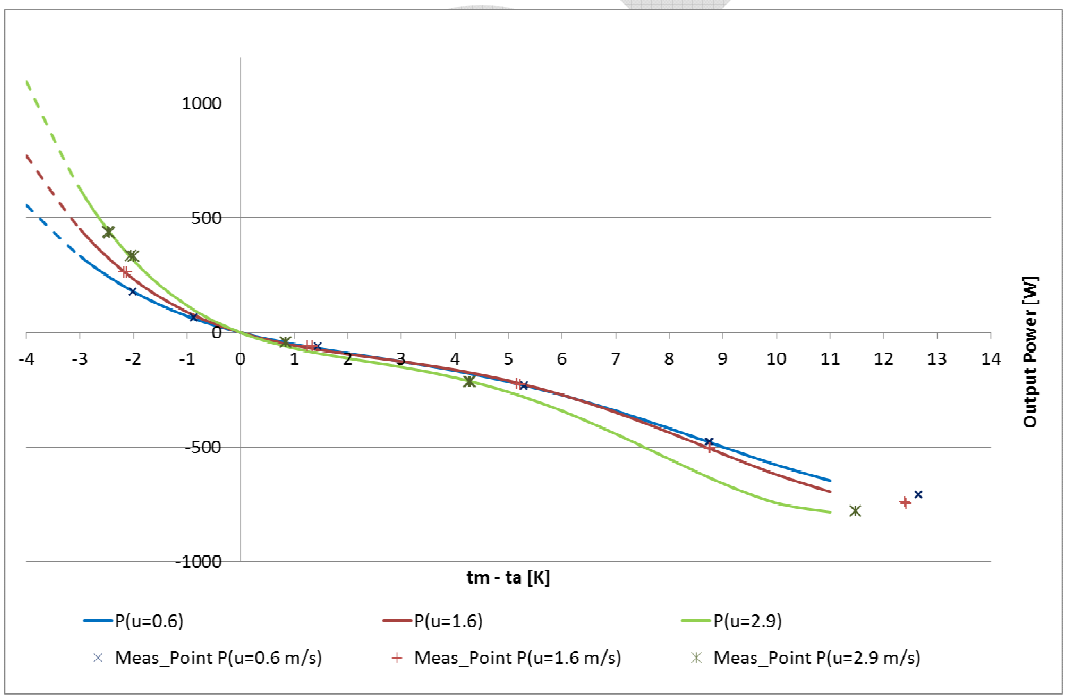

Fig. 5: Measured output power at G"=0 W/m²

Table 2.2: Determination of output Power at net irradiance G''=0 W/m²:

Date	time	m dot	t_in	t_e	Dt_k	t_m	t_a	t_m-t_a	Q	u
[yyyy-mm-dd]	[hh:mm:ss]	[kg/s]	[°C]	[°C]	[K]	[K]	[°C]	[K]	[W]	[m/s]
2012-10-26	16:25:16	0.0352	14.97	17.94	2.97	16.45	18.9	-2.48	436.9	2.9
2012-10-26	16:35:16	0.0352	14.97	17.91	2.95	16.44	18.9	-2.45	433.4	2.9
2012-10-26	18:52:17	0.0351	23.92	22.45	-1.47	23.18	18.9	4.27	-215.1	2.9
2012-10-26	19:02:17	0.0351	23.92	22.46	-1.46	23.19	18.9	4.29	-214.4	2.9
2012-10-26	21:27:17	0.0353	32.90	27.61	-5.28	30.26	18.8	11.48	-778.8	2.9
2012-10-26	21:37:17	0.0353	32.92	27.65	-5.27	30.28	18.8	11.48	-777.8	2.9
2012-10-27	00:47:23	0.0353	19.31	19.03	-0.28	19.17	18.3	0.84	-41.8	2.9
2012-10-27	00:57:23	0.0353	19.30	19.02	-0.28	19.16	18.3	0.85	-41.9	2.9
2012-10-27	14:58:40	0.0350	14.79	17.08	2.29	15.93	18.0	-2.05	335.7	2.9
2012-10-27	15:08:40	0.0350	14.79	17.07	2.27	15.93	17.9	-2.00	332.6	2.9
2012-10-27	18:19:32	0.0349	14.76	16.55	1.80	15.65	17.8	-2.17	263.0	1.6
2012-10-27	18:29:32	0.0349	14.75	16.54	1.79	15.65	17.8	-2.13	261.8	1.6
2012-10-27	21:18:33	0.0351	23.74	22.22	-1.52	22.98	17.8	5.16	-222.9	1.6
2012-10-27	21:28:33	0.0351	23.74	22.20	-1.53	22.97	17.8	5.22	-225.3	1.6
2012-10-27	23:33:33	0.0353	32.82	27.77	-5.05	30.29	17.9	12.43	-745.1	1.6
2012-10-27	23:43:33	0.0353	32.79	27.78	-5.01	30.28	17.9	12.39	-739.1	1.6
2012-10-28	02:43:38	0.0353	19.12	18.74	-0.38	18.93	17.7	1.25	-56.3	1.6
2012-10-28	02:53:38	0.0353	19.13	18.73	-0.40	18.93	17.6	1.34	-58.8	1.6
2012-10-28	16:46:36	0.0350	28.14	24.69	-3.45	26.42	17.7	8.76	-504.6	1.6
2012-10-28	16:56:36	0.0350	28.14	24.69	-3.45	26.42	17.7	8.75	-504.1	1.6
2012-10-28	20:30:28	0.0348	14.68	15.91	1.23	15.30	17.3	-2.00	179.3	0.6
2012-10-28	20:40:29	0.0348	14.66	15.89	1.22	15.28	17.3	-2.00	178.4	0.6
2012-10-28	22:57:29	0.0350	23.65	22.05	-1.61	22.85	17.6	5.29	-235.3	0.6
2012-10-28	23:07:29	0.0350	23.65	22.08	-1.57	22.87	17.6	5.30	-230.2	0.6
2012-10-29	01:22:59	0.0353	32.71	27.92	-4.80	30.31	17.7	12.65	-708.0	0.6
2012-10-29	01:32:59	0.0352	32.73	27.93	-4.80	30.33	17.7	12.65	-706.4	0.6
2012-10-29	05:02:35	0.0351	19.12	18.71	-0.42	18.91	17.5	1.45	-61.1	0.6
2012-10-29	05:12:35	0.0351	19.14	18.72	-0.42	18.93	17.5	1.44	-61.6	0.6
2012-10-29	07:56:35	0.0350	28.17	24.91	-3.26	26.54	17.8	8.73	-478.1	0.6
2012-10-29	08:06:35	0.0350	28.20	24.94	-3.25	26.57	17.8	8.76	-476.6	0.6
2012-10-29	09:30:36	0.0349	16.51	16.97	0.46	16.74	17.6	-0.86	67.2	0.6
2012-10-29	09:40:36	0.0349	16.53	16.97	0.44	16.75	17.6	-0.87	64.6	0.6

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Precisely Right.

Appendix 3: Photo documentation

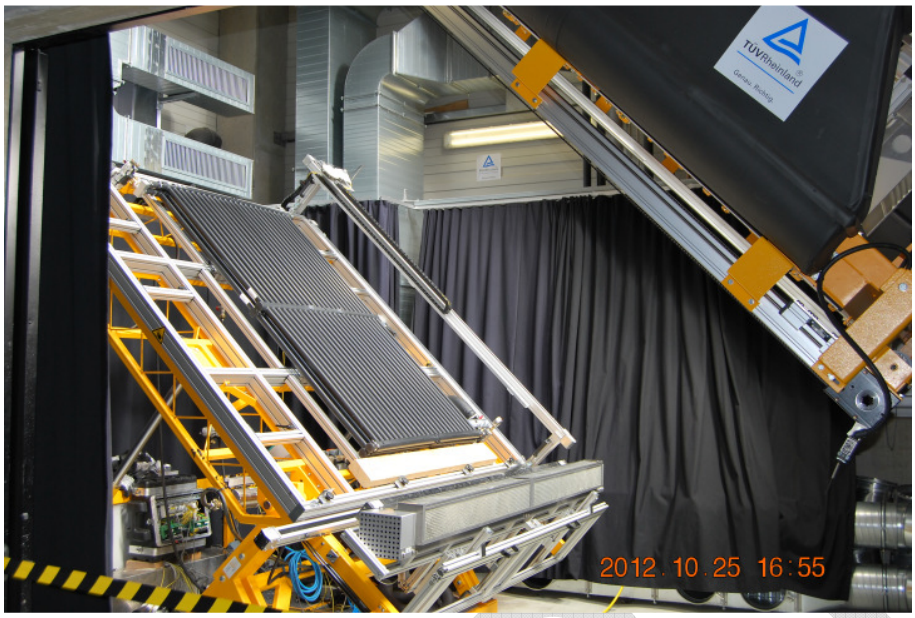

Fig. 6: performance test

Fig. 7: internal barcode

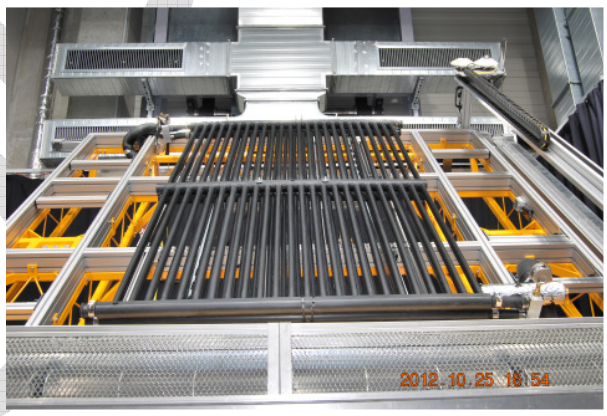

Fig. 8: collector mounting

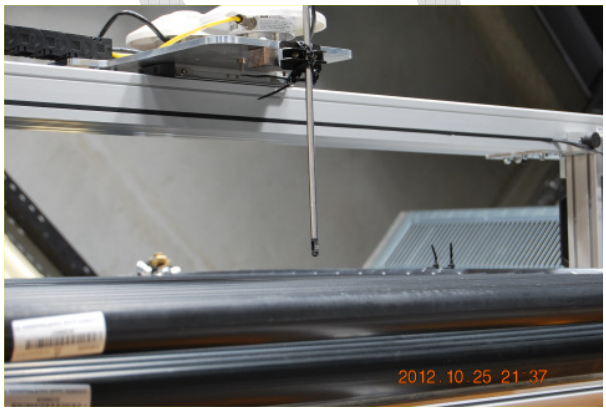

Fig. 9: wind speed detection

Fig. 10: artificial wind generation