Fraunhofer Institut
Solare Energiesysteme

Test Report: KTB Nr. 2006-12-i-k3-en

Efficiency test according to EN 12975-2:2006

for:
IDA Concepts ltd. , England

Brand name:
SPA-58-1800-18-C

Responsible for testing:
Dipl.-Ing. (FH) A. Schäfer

Date:
22nd January 2007

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Accredited according to DIN EN ISO/IEC 17025:2005

Deutscher Akkreditierungs Rat DAR

Registration No.:
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DIN CERTCO
Anerkanntes Prüflaboratorium

Contents

Fraunhofer Institut Solare Energiesysteme

1 Summary

1.1 Preliminary remark to the efficinency meassurement

The tests on SPA-58-1800-18-C have been passed according to EN 12975-1,2:2006.

This report is also valid for the collectors SPA-58/1800-20-C, SPA-58/1800-24-C and SPA-58/1800-30-C. The constructive layout of this collectors is identically to the test collector. Only the number of tubes vary.

As the collector is constructed without a reflector or another defined reflecting backside, the effincy messurements were performed by using a tarpaulin with a defined absorption coefficient of 83 %. This corresponds to typical absorption coefficients of common rooftile.

All test results were taken from KTB 2006-12 from 15th of August 2006.

1.2 Boundary conditions for the collector efficiency parameter determination

Test method:	outdoor, steady state
Latitude:	48.0°
Longitude:	7.8°
Collector tilt:	tracked between 40°and 50°
Collector azimuth:	tracked
Mean irradiation :	986 W/m^2
Mean wind speed:	3 m/s
Mean flow rate:	124 kg/h
Kind of fluid:	water
Period:	July 2006

1.3 Collector efficiency parameters determined

The calculated parameters rely on following areas:

aperture area of 1.706 m^2:	absorber area of 1.451 m^2:
η_{0a} = 0.573	η_{0A} = 0.674
a_{1a} = 2.085 W/m^{2}K	a_{1A} = 2.452 W/m^{2}K
a_{2a} = 0.0083 W/m^{2}K^2	a_{2A} = 0.0098 W/m^{2}K^2

Power output per collector unit [W]:

$t_m - t_a$ [K]	400 [W/m^2]	700 [W/m^2]	1000 [W/m^2]
10	354	647	941
30	272	565	858
50	178	471	764

1.4 Incidence angle modifier - IAM (measured at the outdoor test facility (tracker))

Test method:	outdoor
transversal:	dynamic
longitudinal:	steady state
Latitude:	48.0°
Longitude:	7.8°
Collector tilt:	tracked
Collector azimuth:	tracked

IAM at θ:	0°	10°	20°	30°	40°	50°	60°	70°	73°	80°	90°
transversal:	**1.00**	**1.00**	**1.02**	**1.10**	**1.22**	**1.37**	**1.42**	**1.27**	**1.42**	0.93	0.05
longitudinal:	**1.00**	1.00	1.00	1.00	1.00	**0.96**	0.91	0.79	0.94	0.53	0.00

Table 1: Measured **(bold)** and calculated IAM data for SPA-58-1800-18-C

1.5 Effective thermal capacity of the collector

Effective thermal capacity:

25.90 kJ/K

The effective thermal capacity per sqaure meter is:

15.18 kJ/K m^2

1.6 Tests on efficiency

Test	Date	Result
Date of delivery:	04.05.2006	
Determination of collector parameters	July 2006	passed
Determination of IAM	July 2006	passed
Effective thermal capacity	calculated	performed

1.7 Summary statement

No problems or distinctive observations occured during the measurements.

2 Test Center

Test Center for Thermal Solar Systems of Fraunhofer ISE
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3 Orderer, Expeller, Manufacturer

Expeller	IDA Concepts ltd. The Old Pump House New Street Upton upon Severn Worcs England Tel:+44 (0) 1684 594981 Fax:+44 (0) 1684 594985
Manufacturer	see expeller
Orderer:	see expeller

4 Description of the Collector

4.1 Collector

	(MS) = Manufacturer Specification
Type:	vacuum tube collector with heat pipe conception
Brand name:	SPA-58-1800-18-C
Serial no.:	1-180-18-0001
Year of production:	2006
Number of test collectors:	1
Collector reference no.:	2 KT 54 002 052006
Total area:	2.100 m * 1.487 m = 3.123 m^2 (total dimensions without fittings)
Aperture area:	1.706 m^2 (projected area of the inner diameter of the cover tube)
Absorber area:	1.451 m^2 (MS) (projected area of outer diameter of absorber tubes)
Material of the cover tube:	Borosilcat glas (MS)
Transmission of the cover tube:	n/a (MS)
Outer diameter of the cover tube:	58 mm (MS)
Thickness of the cover tube:	1.5 mm (MS)
Outer diameter of the inner tube	47 mm (MS)
Thickness of the inner tube:	1.5 mm (MS)
Length of the tubes:	1775 mm (MS)
Distance from tube to tube:	80 mm (MS)
Number of tubes:	18 (MS)
Weight empty:	58 kg (MS)
Volume of the fluid:	1.1 l (MS)
Heat transfer fluid:	antifreeze persistent to hight temperatures (MS)

4.2 Absorber

Material of the absorber:	n/a (MS)
Kind/Brand of selective coating:	sputtered (MS)
Absorptivity coefficient α:	93% (MS)
Emissivity coefficient ε:	> 6.5 % (MS)
Material of the absorber pipes:	copper (MS)
Layout of the absorber pipes:	parallel, heat pipes (MS)
Number of absorber pipes:	18 (MS)
Outer diameter:	8 mm (MS)
Inner diameter:	6.8 mm (MS)
Distance between the pipes:	80 mm (MS)
Material of the header pipe:	copper (MS)
Outer diameter of the header pipe:	22 mm (MS)
Inner diameter of the header pipe:	20 mm (MS)
Material of the contact sheets:	aluminium (MS)
Thickness of the contact sheets:	0.2 mm (MS)

4.3 Insulation and Casing

Collector dimensions Height, width, depth:	2.100 m; 1.487 m; 0.156 m
Medium between the inner and outer tubes of the vacuum flask:	$\leq 3 * 10^{-2}$ Pa (MS)
Material of the casing:	high-grade steel (MS)
Sealing material:	silicon (MS)

4.4 Limitations

Maximum pressure:	800 kPa (MS)
Operating pressure:	6 bar (MS)
Maximum service temperature:	125 °C
Maximum stagnation temperature:	250 °C
Flow range recommendation:	1.1 l/m^{2}h (MS)

4.5 Kind of mounting

Flat roof, mounted on the roof:	yes (MS)
Tilted roof, mounted on the roof:	yes (MS)
Tilted roof, integrated:	no (MS)
Free mounting:	yes (MS)
Fassade:	yes (MS)

4.6 Picture and cut drawing of the collector

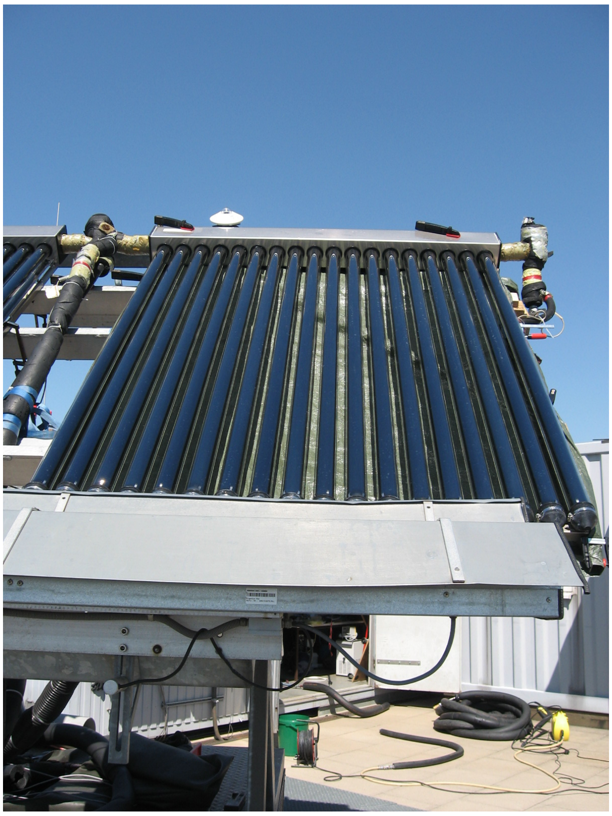

Figure 1: Picture of the collector SPA-58-1800-18-C mounted on the test facility of Fraunhofer ISE

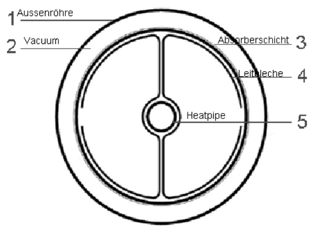

Figure 2: Cut drawing of the vacuum tube

5 Collector efficiency parameters

5.1 Test method

Outdoor, steady state according to EN 12975-2:2006
Thermal solar systems and components, solar collectors, test methods

5.2 Description of the calculation

The functional dependence of the collector efficiency on the meteorological and system operation values can be represented by the following mathematical equation:

$$\eta_{(G,(t_m - t_a))} = \eta_0 - a_{1a}\frac{t_m - t_a}{G} - a_{2a}\frac{(t_m - t_a)^2}{G} \quad (1)$$

(based on aperture area)

with: $t_m = \frac{(t_e + t_{in})}{2}$

where: G = global irradiance on the collector area (W/m^2)
t_{in} = collector inlet temperature (°C)
t_e = collector outlet temperture (°C)
t_a = ambient temperature (°C)

The coefficients η_0, a_{1a} und a_{2a} have the following meaning:

η_0: Efficiency without heat losses, which means that the mean collector fluid temperature is equal to the ambient temperature:

$$\frac{(t_{in} + t_e)}{2} = t_a$$

The coefficients a_{1a} and a_{2a} describe the heat loss of the collector. The temperature depedency of the collector heat loss is described by:

$$a_{1a} + a_{2a} * (t_m - t_a)$$

5.3 Instantaneous efficiency parameters based on aperture and absorber area and mean temperature of heat transfer fluid

Boundary conditions:

Test method:	outdoor, steady state
Latitude:	48.0°
Longitude:	7.8°
Collector tilt:	tracked between 40°and 50°
Collector azimuth:	tracked

Test conditions:

Mean irradiation :	986 W/m^2
Mean wind speed:	3 m/s
Mean flow rate:	124 kg/h
Kind of fluid:	water

Results:
The calculated parameters rely on following areas[1]:

aperture area (1.706 m^2):	absorber area (1.451 m^2):
η_{0a} = 0.573	η_{0A} = 0.674
a_{1a} = 2.085 W/m^{2}K	a_{1A} = 2.452 W/m^{2}K
a_{2a} = 0.0083 W/m^{2}K^2	a_{2A} = 0.0098 W/m^{2}K^2

The determination for the standard deviation (k=2) was performed according ENV 13025 (GUM). Based on this calculation the uncertainty is less than 2%-points of the efficiency values over the complete measured temperature range (η_{0a} = 0.573 +/- 0.02). Based on our experience with the test facilities the uncertainty is much smaller and in a range of **+/- 1%-point**. The standard deviation of the heat loss parameters resulting from the regression fit curve through the measurements points is:
a_{1a} = 2.085 +/- 0.087 and
a_{2a} = 0.0083 +/- 0.0012 .

[1]absorber area - projected area of absorber tube,
aperture area - projected area of inner diameter of cover tube

5.4 Power output per collector unit

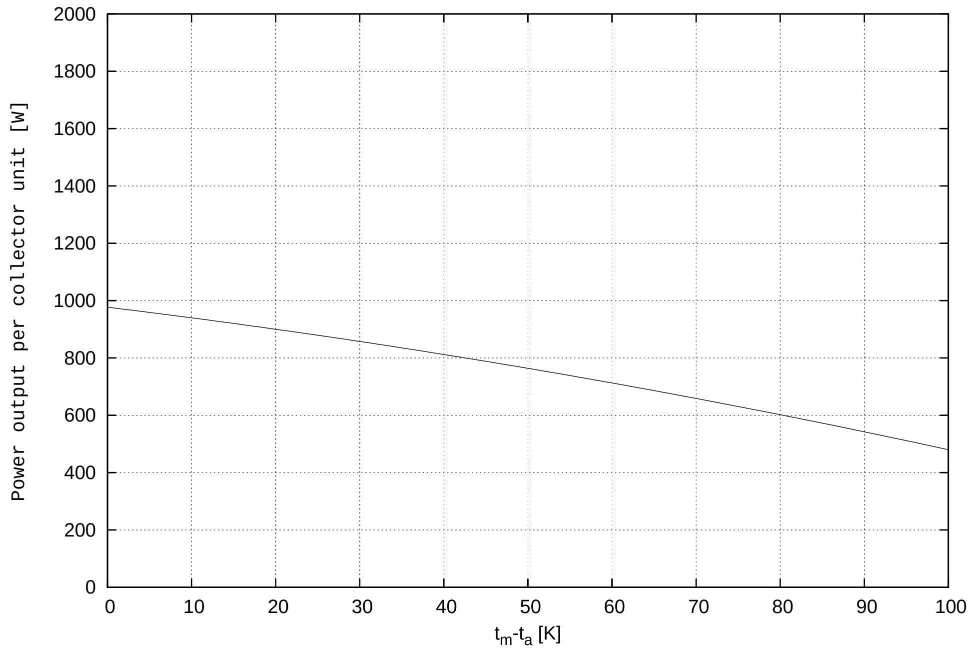

Figure 3: Power output per collector unit based on an irradiance of 1000 W/m^2

Power output per collector unit [W]:

$t_m - t_a$ [K]	400 [W/m^2]	700 [W/m^2]	1000 [W/m^2]
10	354	647	941
30	272	565	858
50	178	471	764

For more detailed data and the callculated efficiency curve please see annex B.

6 Incidence angle modifier IAM

The Incidence angle modifier IAM is a correction factor representing how the angel of radiation affects the performance of a collector. The IAM is described by a longitudinal and a transversal component.
IAM longitudinal:
The tilt angle of the collector in combination with the zenith angle of the sun results in the incident angle theta (=θ) in longtitudinal direction.
IAM transversal:
The orientation angle of the collector in combination with the azimuth angle of the sun results in the incident angle theta (=θ) in transversal direction.

The transversal measurement was performed dynamically, what means that the orientation of the tracker was fixed, just the tilt angle was tracked. So the sun is turning around the collector and there is no longitudinal influence (transversal at the present collector means transversal to the ligament of the cover). The incident angle is changing during the day. The resulting values for the incident angle θ are the mean values between the east and the west measurement.
For the measurement of the IAM longitudinal the orientation and the tilt angle of the tracker were tracked, which means a steady state measurement.

Test method:	outdoor
transversal:	dynamic
longitudinal:	steady state
Latitude:	48.0°
Longitude:	7.8°
Collector tilt:	tracked
Collector azimuth:	tracked

IAM at θ:	0°	10°	20°	30°	40°	50°	60°	70°	73°	80°	90°
transversal:	**1.00**	**1.00**	**1.02**	**1.10**	**1.22**	**1.37**	**1.42**	**1.27**	**1.42**	0.93	0.05
longitudinal:	**1.00**	1.00	1.00	1.00	1.00	**0.96**	0.91	0.79	0.94	0.53	0.00

Table 2: Measured **(bold)** and calculated IAM data for SPA-58-1800-18-C

The IAM longitudinal was measured for one angle θ = 50°. All other angles for the IAM longitudinal in table 2 were calculated according to Ambrosetti [1](equation 2).

$$K_\theta = 1 - [tan\frac{\theta}{2}]^{\frac{1}{r}} \tag{2}$$

7 Effective thermal capacity of the collector

The effective thermal capacity of the collector is calculated according to section 6.1.6.2 of EN 12975-2:

25.90 kJ/K

The effective thermal capacity per sqaure meter is:

15.18 kJ/K m^2

[1]P.Ambrosetti. Das neue Bruttowärmeertragsmodell für verglaste Sonnenkollektoren, Teil 1 Grundlagen. EIR, Wurenlingen 1983

8 Final inspection

An overview of the result of the final inspection shows the following table.

Collector component	Potential problem	Evaluation
Collector box/ fasteners	Cracking/ wraping/ corrosion/ rain penetration	0
Mountings/ structure	Strength/ safety	0
Seals/ gaskets	Cracking/ adhesion/ elasticity	0
Cover/ reflector	Cracking/ crazing/ buckling/ delamination/ wraping/ outgassing	0
Absorber coating	Cracking/ crazing/ blistering	0
Absorber tubes and headers	Deformation/ corrosion/ leakage/ loss of bonding	0
Absorber mountings	Deformation/ corrosion	0
Insulation	Water retention/ outgassing/ degradation	0

0: No problem
1: Minor problem
2: Severe problem
x: Inspection to establish the condition was not possible

9 Collector identification

The collector identification/documentation according EN 12975-1 chapter 7 was complete, see the following items:

- Drawings and data sheet
- Labeling of the collector
- Installer instruction manual
- List of used materials

10 Summary statement

The measurements were carried out in July 2006.

No problems or distinctive observations occured during the measurements.

11 Annotation to the test report

The results described in this test report refer only to the test collector. It is not allowed to make extract copies of this test report.

Test report: KTB Nr. 2006-12-i-k3-en

Freiburg 22nd January 2007
Fraunhofer-Institute for IDA Concepts ltd

Dipl.-Phys. M. Rommel Head of the Test Center for Thermal Solar Systems	Dipl.-Ing. (FH) A. Schäfer Responsible for testing

A Drawing of absorber layout

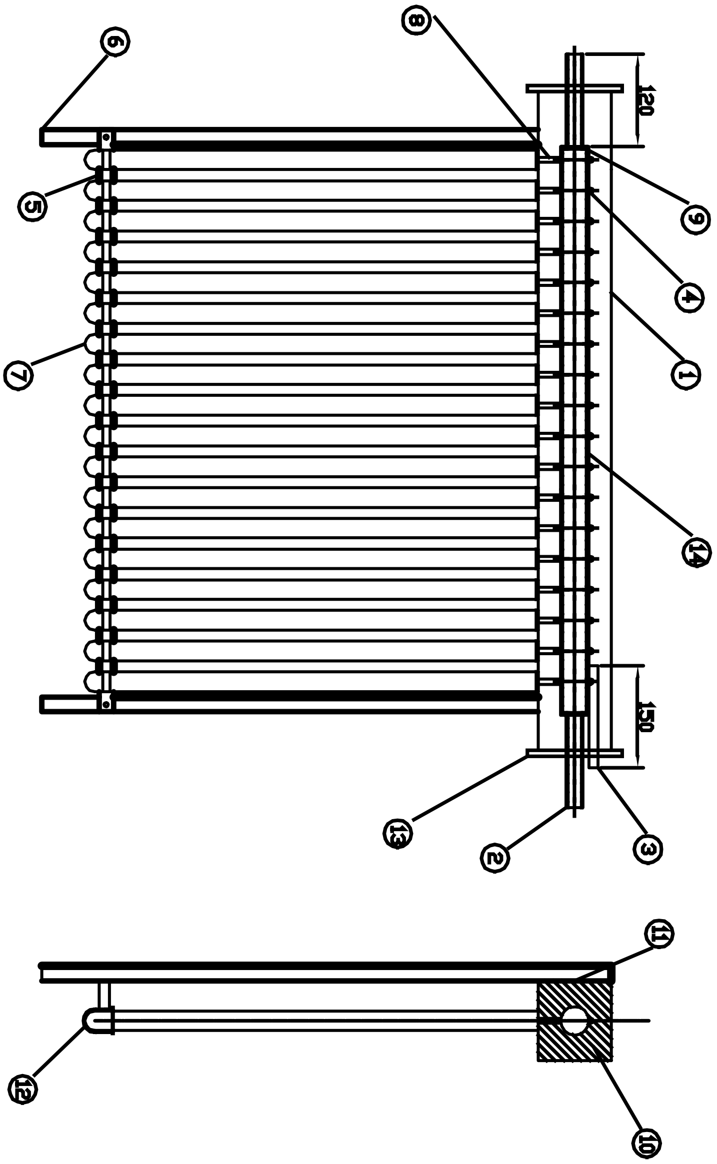

Figure 4: Drawing of absorber layout SPA-58-1800-18-C

B Efficiency curve and measured data

B.1 Efficiency curve with measurement points based on aperture area 1.706 m^2

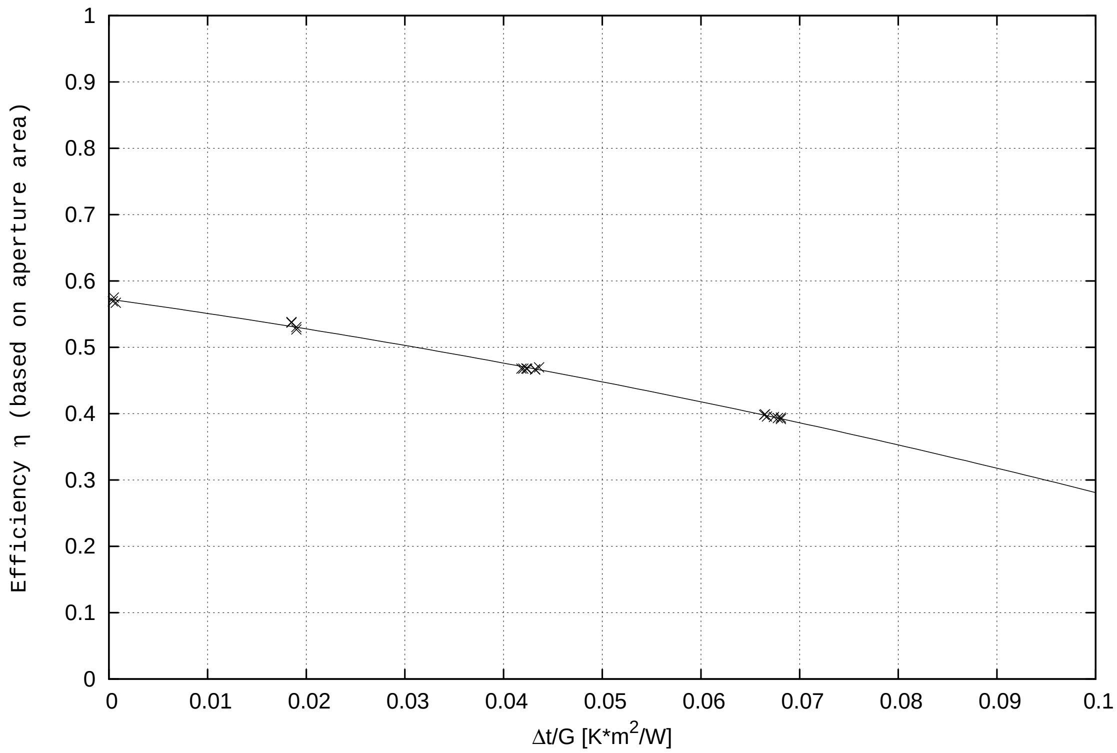

Figure 5: Efficiency curve with measurement points based on aperture area 1.706 m^2

Results:
The calculated parameters rely on following areas:

aperture area of 1.706 m^2:	absorber area of 1.451 m^2:
η_{0a} = 0.573	η_{0A} = 0.674
a_{1a} = 2.085 W/m^2K	a_{1A} = 2.452 W/m^2K
a_{2a} = 0.0083 W/m^2K^2	a_{2A} = 0.0098 W/m^2K^2

B.2 Efficiency curve for the determined coefficients and for an assumed irradiation of 800 W/m^2 based on aperture area

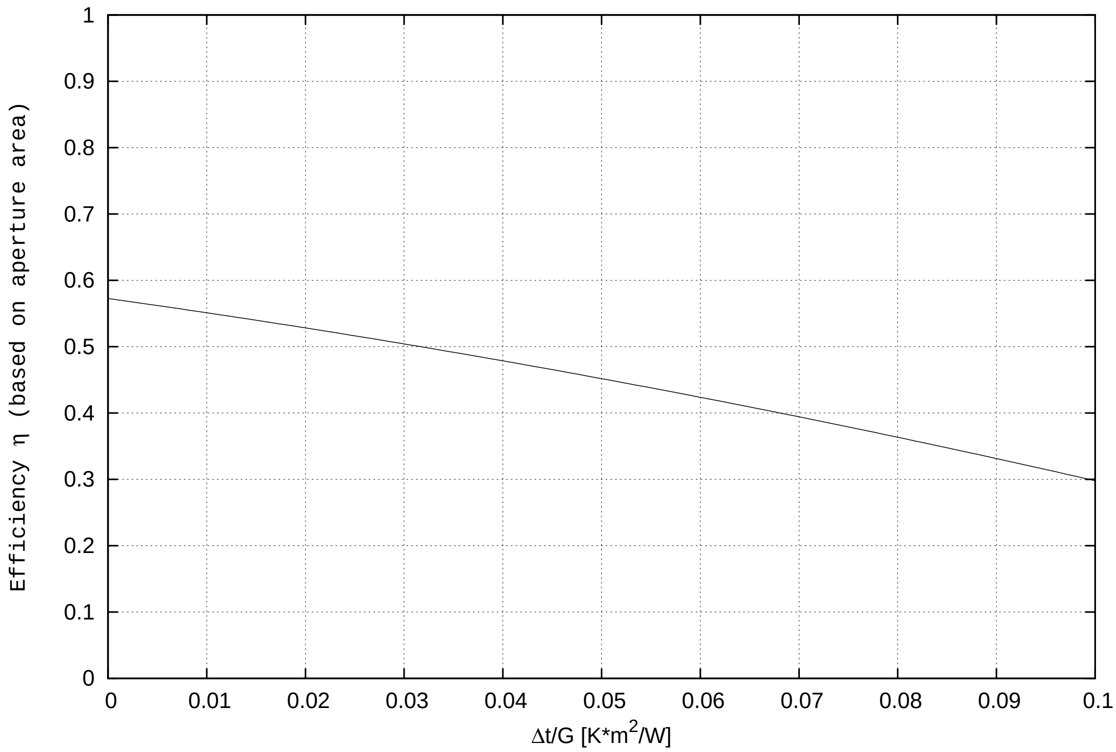

Figure 6: Efficiency curve scaled to 800 W/m^2 based on aperture area 1.706 m^2

The calculated parameters rely on following areas:

aperture area:	absorber area:
$\eta_{0.05a}$ = 0.452	$\eta_{0.05A}$ = 0.532

$\eta_{0.05}$ is the efficiency of the collector for follwing conditons (for example): an irradiation of 800 W/m^2, an ambient temperature of 20°C and a mean collector temperture of 60°C. These are typical conditions for solar domestic hot water systems.

B.3 Measured data for efficiency curve

G [W/m^2]	G_d/G [-]	m [kg/h]	t_{in} [°C]	t_e [°C]	$t_e - t_{in}$ [K]	t_m [°C]	t_a [°C]	$t_m - t_a$ [K]	$(t_m - t_a)/G$ [K m^2/W]	η_a [-]
995	0.07	124.2	23.12	29.79	6.67	26.45	25.76	0.70	0.0007	0.567
996	0.07	124.3	23.14	29.84	6.70	26.49	26.09	0.39	0.0004	0.569
993	0.08	124.3	23.16	29.91	6.75	26.53	26.06	0.47	0.0005	0.575
991	0.08	124.2	23.17	29.88	6.71	26.53	26.71	-0.19	-0.0002	0.573
991	0.08	124.1	23.21	29.93	6.72	26.57	26.80	-0.23	-0.0002	0.573
970	0.08	125.1	46.73	52.73	6.00	49.73	31.35	18.38	0.0190	0.527
966	0.08	124.5	46.73	52.77	6.04	49.75	31.38	18.37	0.0190	0.530
970	0.09	123.5	46.97	53.17	6.20	50.07	32.15	17.91	0.0185	0.537
966	0.09	123.6	46.96	53.13	6.18	50.05	32.15	17.89	0.0185	0.538
989	0.08	125.3	69.29	74.72	5.43	72.00	28.93	43.07	0.0436	0.470
987	0.08	125.1	69.33	74.72	5.39	72.03	29.35	42.68	0.0432	0.467
984	0.08	125.1	69.35	74.73	5.38	72.04	29.60	42.45	0.0432	0.467
980	0.08	125.2	69.38	74.75	5.37	72.06	30.53	41.53	0.0424	0.468
981	0.08	125.0	69.35	74.73	5.38	72.04	30.53	41.51	0.0423	0.468
981	0.08	125.0	69.34	74.72	5.38	72.03	31.00	41.03	0.0418	0.468
983	0.08	125.1	69.35	74.73	5.39	72.04	30.82	41.22	0.0420	0.468
993	0.07	123.8	91.39	95.98	4.59	93.69	26.04	67.64	0.0681	0.392
993	0.07	123.6	91.40	96.03	4.62	93.72	26.04	67.68	0.0681	0.394
999	0.07	123.4	91.34	95.99	4.65	93.66	25.91	67.76	0.0678	0.393
999	0.07	123.4	91.39	96.06	4.67	93.72	26.37	67.35	0.0674	0.395
998	0.07	123.4	91.44	96.11	4.67	93.77	27.18	66.59	0.0667	0.396
995	0.07	123.6	91.51	96.19	4.69	93.85	27.70	66.15	0.0665	0.399
996	0.07	123.6	91.51	96.19	4.68	93.85	27.64	66.21	0.0664	0.398

Table 3: Data of measured efficiency points