

# Test Report: KTB Nr. 2006-12-a-en-k

## Efficiency test according to EN 12975-2:2006

### For:

Heliosberg

### Brand name:

SPA-58-1800-18-C

### Responsible for testing:

Dipl.-Ing. (FH) A. Schäfer

### Date:

17th August 2006

### Address:

Fraunhofer-Institute for Solar Energy Systems ISE

Heidenhofstraße 2, D-79110 Freiburg

Tel. +49-761-4588-5354; Fax. +49-761-4588-9354

E-mail: arim.schaefer@ise.fraunhofer.de

Internet: www.kollektortest.de

Accredited according to DIN EN ISO/IEC 17025:2005

Registration No.:

DAP-PL-3926.00

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## 1 Summary

### 1.1 Preliminary remark to the efficiency measurement

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 are identically to the test collector. Only the number of tubes varies.

As the collector is constructed without a reflector or another defined

Reflecting backside, the efface measurements were performed by using a Tarpaulin with a defined emission coefficient of 83 %. This corresponds to

The emission coefficients of comment roof tile.

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

This report is a translation to English.

### 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<sup>2</sup>

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<sup>2</sup>: absorber area of 1.451 m<sup>2</sup>:

$\tau_{0a} = 0.573$   $\tau_{0A} = 0.674$

$a_{1a} = 2.085$  W/m<sup>2</sup>K  $a_{1A} = 2.452$  W/m<sup>2</sup>K

$a_{2a} = 0.0083$  W/m<sup>2</sup>K<sup>2</sup>  $a_{2A} = 0.0098$  W/m<sup>2</sup>K<sup>2</sup>

Power output per collector unit [W]:

$t_m - t_a$  [K] 400 [W/m<sup>2</sup>] 700 [W/m<sup>2</sup>] 1000 [W/m<sup>2</sup>]

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  $\gamma$ : 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 square meter is:  
15.18 kJ/K m<sup>2</sup>

### 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 occurred during the measurements.

## 2 Test Center

Test Center for Thermal Solar Systems of Fraunhofer ISE

Heidenhofstraße 2, D-79110 Freiburg

Tel.: +49-761-4588-5354 or -5141; Fax. +49-761-4588-9354

E-mail: arim.schaefer@ise.fraunhofer.de; rommel@ise.fraunhofer.de.

Internet: <http://www.kollektortest.de>

## 3 Description of the Collector

### 3.1 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<sup>2</sup>

(Total dimensions without fittings)

Aperture area: 1.706 m<sup>2</sup>

(Projected area of the inner diameter

Of the cover tube)

Absorber area: 1.451 m<sup>2</sup> (MS)

(Projected area of outer diameter of

Absorber tubes)

Material of the cover tube: Borosilicate glass (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 high temperatures  
(MS)

### 3.2 Absorber

Material of the absorber: N/A (MS)  
 Kind/Brand of selective coating: sputtered (MS)  
 Absorptivity coefficient  $\alpha$ : 93% (MS)  
 Emissivity coefficient  $\epsilon$ : > 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: 1 mm (MS)  
 Material of the contact sheets: aluminium (MS)  
 Thickness of the contact sheets: 0.2 mm (MS)

### 3.3 Insulation and Casing

Collector dimensions  
 Height, width, depth: 2.100 m; 1.487 m; 1.560 m  
 Medium between the inner and  
 Outer tubes of the vacuum flask:  
 $3 \times 10^{-2}$  Pa (MS)  
 Material of the casing: high-grade steel (MS)  
 Sealing material: silicon (MS)

### 3.4 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<sup>2</sup>h (MS)

### 3.5 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)

### 3.6 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

## 4 Collector efficiency parameters

### 4.1 Test method

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

### 4.2 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:

$$\eta(G, (t_m - t_a)) = \eta_0 - a_1 \frac{G}{G_0} - a_2 \frac{(t_m - t_a)}{G}$$

$$t_m - t_a$$

$$G - a_2 a$$

$$(t_m - t_a)^2$$

$$G$$

(1)

(based on aperture area)

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

2

where: G = global irradiance on the collector area (W/m<sup>2</sup>)

t<sub>in</sub> = collector inlet temperature (°C)

t<sub>e</sub> = collector outlet temperature (°C)

t<sub>a</sub> = ambient temperature (°C)

The coefficients  $\eta_0$ , a<sub>1a</sub> und a<sub>2a</sub> have the following meaning:

$\eta_0$ : Efficiency without heat losses, which means that the mean collector

Fluid temperature is equal to the ambient temperature:

$$(t_{in} + t_e)$$

2

$$= t_a$$

The coefficients a<sub>1a</sub> and a<sub>2a</sub> describe the heat loss of the collector. The

Temperature dependency of the collector heat loss is described by:

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

### 4.3 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<sup>2</sup>

Mean wind speed: 3 m/s

Mean flow rate: 124 kg/h

Kind of fluid: water

Results:

The calculated parameters rely on following areas<sub>1</sub>:

Aperture area absorber area

(1.706 m<sup>2</sup>): (1.451 m<sup>2</sup>):

$$\eta_{0a} = 0.573 \quad \eta_{0A} = 0.674$$

$$a_{1a} = 2.085 \text{ W/m}^2\text{K} \quad a_{1A} = 2.452 \text{ W/m}^2\text{K}$$

$$a_{2a} = 0.0083 \text{ W/m}^2\text{K}^2 \quad a_{2A} = 0.0098 \text{ W/m}^2\text{K}^2$$

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 (  $\eta_{0a} = 0.573 \pm 0.02$ ). 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:

$$a_{1a} = 2.085 \pm 0.087 \text{ and}$$

$$a_{2a} = 0.0083 \pm 0.0012 .$$

<sub>1</sub>absorber area - projected area of absorber tube,

Aperture area - projected area of inner diameter of cover tube

### 4.4 Power output per collector unit

0

200

400

600

800

1000

1200

1400

1600

1800

2000

0 10 20 30 40 50 60 70 80 90 100

Power output per collector unit [W]

t<sub>m</sub>-t<sub>a</sub> [K]

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

Power output per collector unit [W]:  
 $t_m - t_a$  [K] 400 [W/m<sup>2</sup>] 700 [W/m<sup>2</sup>] 1000 [W/m<sup>2</sup>]  
 10 354 647 941  
 30 272 565 858  
 50 178 471 764

For more detailed data and the calculated efficiency curve please see Annex B.

## 5 Incidence angle modifiers IAM

The Incidence angle modifier IAM is a correction factor representing how the angle 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  $\theta$  (=  $\theta_l$ ) in longitudinal direction.

IAM transversal:

The orientation angle of the collector in combination with the azimuth angle of the sun results in the incident angle  $\theta$  (=  $\theta_t$ ) 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  $\theta$  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  $\theta$ : 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  $\theta = 50^\circ$ . All other angles

for the IAM longitudinal in table 2 were calculated according to Ambrosetti (equation 2).

$K_t = 1 - \left[ \frac{\theta}{\theta_{max}} \right]^2$

—

]

1

(2)

## 6 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 square meter is:

15.18 kJ/K m<sup>2</sup>

1P.Ambrosetti. Das neue Bruttowärmeertragsmodell für verglaste Sonnenkollektoren, Teil

1 Grundlagen. EIR, Würenlingen 1983

## 7 Final inspection

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

Collector component	Potential problem	Evaluation
Collector box/ fasteners	Cracking/ wrapping/ corrosion/ Rain penetration	0
Mountings/ structure	Strength/ safety	0
Seals/ gaskets	cracking/ adhesion/ elasticity	0
Cover/ reflector	Cracking/ crazing/ buckling/ delaminating/ Wrapping/ out gassing	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/ out gassing/ Degradation	0

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

## 8 Collector identification

The collector identification/documentation according EN 12975-1 chapter 7

Was complete, see the following items:

- \_ Drawings and data sheet
- \_ labelling of the collector
- \_ Installer instruction manual
- \_ List of used materials

## 9 Summary statements

The measurements were carried out in July 2006.

No problems or distinctive observations occurred during the measurements.

## 10 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-a-en-k

Freiburg, 17th August 2006

Fraunhofer-Institute for Solar Energy Systems ISE

Dip.-Phys. M. Rommel Dipl.-Ing. (FH) A. Schäfer

Head of the Test Center for Responsible for testing

Thermal Solar Systems

## 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<sup>2</sup>

0	
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	
1	
0	0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Efficiency $\eta$ (based on aperture area)	
$\Delta t/G$ [K*m <sup>2</sup> /W]	

Figure 5: Efficiency curve with measurement points based on aperture area 1.706 m<sup>2</sup>

**Results:**

The calculated parameters rely on following areas:

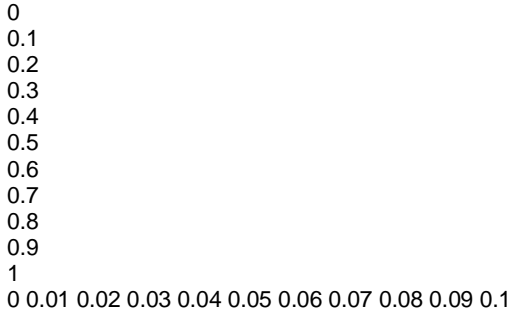
Aperture area of 1.706 m<sup>2</sup>: absorber area of 1.451 m<sup>2</sup>:

$$\eta_{0a} = 0.573 \quad \eta_{0A} = 0.674$$

$$a_{1a} = 2.085 \text{ W/m}^2\text{K} \quad a_{1A} = 2.452 \text{ W/m}^2\text{K}$$

$$a_{2a} = 0.0083 \text{ W/m}^2\text{K}^2 \quad a_{2A} = 0.0098 \text{ W/m}^2\text{K}^2$$

**B.2 Efficiency curve for the determined coefficients and for an assumed irradiation Of 800 W/m<sup>2</sup> based on aperture area**



Efficiency  $\eta$  (based on aperture area)

$\Delta t/G$  [K\*m<sup>2</sup>/W]

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

The calculated parameters rely on following areas:

Aperture area: absorber area:

$$\eta_{0.05a} = 0.452 \quad \eta_{0.05A} = 0.532$$

$\eta_{0.05}$  is the efficiency of the collector for following conditions (for example):

An irradiation of 800 W/m<sup>2</sup>, an ambient temperature of 20°C and a mean Collector temperature of 60°C. These are typical conditions for solar Domestic hot water systems.

**B.3 Measured data for efficiency curve**

$G_d/G_m$   $t_{in}$   $t_{e}$   $t_c$   $t_m$   $t_a$   $t_m - t_a$   $(t_m - t_a)/G_a$

[W/m<sup>2</sup>] [-] [kg/h] [°C] [°C] [K] [°C] [°C] [K] [K m<sup>2</sup>/W] [-]

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