Fraunhofer
ISE

Test Report: KTB Nr. 2006-39-a-en

# Collector test according to EN 12975-1,2:2006

**for:**
TWL-Technologie GmbH, Deutschland

**Brand name:**
FK200

**Responsible for testing:**
Dipl.-Ing. (FH) K. Kramer

**Date of issue:**
6th December 2011
**Date of reissue:**
31st January 2012

**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: pzts@ise.fraunhofer.de
Internet: www.kollektortest.de

Accredited according to DIN EN ISO/IEC 17025:2005

Deutscher Akkreditierungs Rat DAR

ilac-MRA

DIN CERTCO Anerkanntes Prüflaboratorium

Registration No.:
DAP-PL-3926.00

# Contents

# 1 Summary

## 1.1 Preliminary remark

The tests have been passed according to EN 12975-1,2:2006. Main purpose for testing has been, to fulfill all requirements for the SolarKeymark label. All requirements have been met.
The present report is valid for the collector series FK 8200 N 4A Cu-Al-P , FK 8230 N 4A Cu-Al-P, FK 8250 N 4A Cu-Al-P and the collector series FK 8200 L 2A Cu-Al-P , FK 8230 L 2A Cu-Al-P, FK 8250 L 2A Cu-Al-P . All test results have been taken over from the test reports ktb-2006-35-ken and ktb-2006-36-en. The tests were performed at the largest collector and at the smallest collector of the series, according to the rules of the SolarKeymark (Version 8.00 of January 2003).
The report is also valid for the collector FK200 of the company TWL-Technologie GmbH, as it is technically identical with the collector FK 8230 N4A Cu-Al-P from the company GREENoneTEC Solarindustrie GmbH .

Alike the certificate of the collector minimum gain of 525 kwh/m$^2$a is handed.

## 1.2 Collector efficiency parameters determined

Results:
The calculated parameters are based on following areas:

| aperture area of 1.924 m$^2$: | absorber area of 1.840 m$^2$: |
|---|---|
| $\eta_{0a}$ = 0.759 | $\eta_{0A}$ = 0.794 |
| $a_{1a}$ = 3.480 W/m$^2$K | $a_{1A}$ = 3.639 W/m$^2$K |
| $a_{2a}$ = 0.0161 W/m$^2$K$^2$ | $a_{2A}$ = 0.0168 W/m$^2$K$^2$ |

## 1.3 Incidence angle modifier - IAM

| $\theta$: | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_\theta$: | **1.00** | 1.00 | **0,99** | **0.98** | **0.95** | **0.899** | **0.81** | 0.66 | 0.41 | 0.00 |

Table 1: Measured **(bold)** and calculated IAM data for FK 8200 N 4A Cu-Al

Fraunhofer ISE

## 1.4 Pressure drop

The pressure drop in mbar can be described by the following function of the mass flow x in kg/h:

$$\Delta p = 0.004 \ * x + 1.187 * 10^{-5} \ * x^2 \quad (1)$$

## 1.5 Effective thermal capacity of the collector

Effective thermal capacity (FK 8200 N 4A Cu-Al ):

11.01 kJ/K

The effective thermal capacity per square meter is (valid for the series):

5.72 kJ/K $m^2$

## 1.6 Schedule of tests and callculations

| Test | Date | Result |
|---|---|---|
| Date of delivery: | 3rd March 2006<br>30th March 2006 | |
| 1st internal pressure | 11th October 2006 | passed |
| High temperature resistance | 23th August 2006 | passed |
| Exposure | 8th August 2006 -<br>18th October 2006 | passed |
| 1st external thermal shock | 1th September 2006 | passed |
| 2nd external thermal shock | 17th October 2006 | passed |
| 1st internal thermal shock | 31th August 2006 | passed |
| 2nd internal thermal shock | 20th October 2006 | passed |
| Rain penetration | 1th September 2006 | passed |
| Freeze resistance | | not relevant |
| 2nd internal pressure | 18th October 2006 | passed |
| Mechanical load | 9th November 2006 | passed |
| Stagnation temperature | | 184.4 °C |
| Final inspection | 9th November 2006 | passed |
| Determination of collector parameters | 18th - 21st April 2006 | passed |
| Determination of IAM | April 2006 | passed |
| Effective thermal capacity | | 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
Heidenhofstraße 2, D-79110 Freiburg
Tel.: +49-761-4588-5354; Fax.: +49-761-4588-9354
E-mail: pzts@ise.fraunhofer.de
Internet: http://www.kollektortest.de

## 3 Orderer, Expeller, Manufacturer

| | |
|---|---|
| Orderer: | GREENoneTEC Solarindustrie GmbH<br>Energieplatz 1<br>9300 St. Veit / Glan<br>Austria<br>Tel: +43 (0) 4212 28 136 168<br>Fax: +43 (0) 4212 28 136 165 |
| Expeller: | TWL-Technologie GmbH<br>Im Gewerbegebiet 8-22<br>92271 Freihung<br>Deutschland<br>Tel: +49 9646 80918-10<br>Fax: +49 9646 80118-29 |
| Expeller and Manufacturer: | see orderer |

# 4 Overview of series FK 8000 collectors

According to the SolarKeymark rules there is a agreement concerning collectors wich differ only in size, so called series. Only the biggest and the smallest collector have to be tested in this case. A complete collector test according to EN 12975-1,2 has to be performed at the biggest collector. The efficiency test only is sufficient at the smallest collector. The SolarKeymark label based on this tests is valid for the whole series.

(MS) = Manufacturer Specification

| Brand name | Size of total area (MS) [$m^2$] | Size of absorber area (MS) [$m^2$] |
|---|---|---|
| FK 8200 N 4A Cu-Al-P | 2.025 | 1.840 |
| FK 8230 N 4A Cu-Al-P | 2.340 | 2.140 |
| FK 8250 N 4A Cu-Al-P | 2.515 | 2.310 |
| FK 8200 L 2A Cu-Al-P | 2.024 | 1.840 |
| FK 8230 L 2A Cu-Al-P | 2.340 | 2.140 |
| FK 8250 L 2A Cu-Al-P | 2.516 | 2.310 |

# 5 Description of the Collector

| | (MS): Manufacturer Spezification |
|---|---|
| Typ: | Flat-Plate-Collector, Harpe Absorber |
| Material of the cover: | solar glass,<br>prismatic structured (HA) |
| Number of covers: | 1 |
| Transmission of cover: | $\geq$ 90.8 % $\pm$ 2 % (MS) |
| Thickness of cover: | 4 mm (MS)<br>3.2 mm (MS) |

## 5.1 Specific data of the smallest collector of the series FK 8000 N4A-Cu-Al

| | |
|---|---|
| Brand name: | FK 8200 N 4A Cu-Al |
| Serial no.: | 06/11001 |
| Year of production: | 2006 |
| Number of test collectors: | 1 |
| Collector reference no.: | 2-KT-50 11 032006 |
| Collector dimensions | |
| Height, width, depth | 1.731 m, 1.170 m, 0.084 m |
| Total area: | 1.731 m * 1.170 m = 2.025 $m^2$ |
| Aperture area: | 1.695 m * 1.135 m = 1.924 $m^2$ |
| Absorber area: | 1.105 m * 1.666 m = 1.840 $m^2$ |
| Number of absorber pipes | 12 (MS) |
| Weight empty: | 37.1 kg |
| Volume of the fluid: | 1.5 l (MS) |
| Heat transfer fluid | propylene glycol/Water (MS) |

## 5.2 Specific data of the smallest collector of the series FK 8000 L2A-Cu-Al

| | |
|---|---|
| Brand name: | FK 8200 L 2A Cu-Al |
| Number of test collectors: | 0 |
| Collector dimensions | |
| Height, width, depth | 1.730 m, 1.170 m, 0.083 m (MS) |
| Total area: | 1.730 m x 1.170 m = 2.024 $m^2$ (MS) |
| Aperture area: | 1,91 $m^2$ (MS) |
| Absorber area: | 1.668 m * 1.105 m = 1.840 $m^2$ (MS) |
| Number of absorber pipes | 12 (MS) |
| Weight empty: | no declaration |
| Volume of the fluid: | 1.5 l (MS) |
| Heat transfer fluid | propylene glycol/Water (MS) |

## 5.3 Specific data of the largest collector of the series FK 8000 N4A-Cu-Al

| | |
|---|---|
| Brand name: | FK 8250 N 4A Cu-Al |
| Serial no.: | 0603 |
| Year of production: | 2006 |
| Number of test collectors: | 1 |
| Collector reference no.: | 2-KT-50 18 032006 |
| Collector dimensions | |
| Height, width, depth | 2.151 m, 1.170 m, 0.084 m (MS) |
| Total area: | 2.151 m * 1.170 m = 2.517 $m^2$ |
| Aperture area: | 2.111 m * 1.133 m = 2.392 $m^2$ |
| Absorber area: | 2.090 m * 1.105 m = 2.309 $m^2$ (MS) |
| Number of absorber pipes | 12 (MS) |
| Weight empty: | 47 kg (MS) |
| Volume of the fluid: | 1.7 l (MS) |
| Heat transfer fluid | propylene glycol/Water (MS) |

## 5.4 Specific data of the largest collector of the series FK 8000 L2A-Cu-Al

| | |
|---|---|
| Brand name: | FK 8250 L 2A Cu-Al |
| Number of test collectors: | 0 |
| Collector dimensions | |
| Height, width, depth | 2.150 m, 1.170 m, 0.083 m (MS) |
| Total area: | 2.150 m * 1.170 m = 2.516 $m^2$ |
| Aperture area: | 2.390 $m^2$ (MS) |
| Absorber area: | 2.088 m * 1.105 m = 2.310 $m^2$ (MS) |
| Number of absorber pipes | 12 (MS) |
| Weight empty: | no declaration |
| Volume of the fluid: | 1.7 l (MS) |
| Heat transfer fluid | propylene glycol/Water (MS) |

## 5.5 Absorber

| | |
|---|---|
| Material of the absorber sheet: | Aluminium (MS) |
| Thickness of the absorber sheets: | 0.5 mm (MS) |
| Kind of the selective coating: | BlueTec; Eta plus (MS) |
| | Alanod; Mirrotherm (MS) |
| Absorptivity coefficient $\alpha$: | 94.0 % $\pm$ 2% (MS) |
| Emissivity coefficient $\varepsilon$: | 5 % $\pm$ 2% (MS) |
| Material of the absorber pipes: | Copper (MS) |
| Layout of the absorber pipes: | harpe, double harpe (MS) |
| Outer diameter: | 8 mm (MS) |
| Inner diameter: | 7 mm (MS) |
| Distance between the pipes: | 96 mm (MS) |
| Material of the header pipe: | Copper (MS) |
| Outer diameter of the header pipe: | 22 mm (MS) |
| Inner diameter of the header pipe: | 20.4 mm (MS) |

## 5.6 Insulation and Casing

| | |
|---|---|
| Thickness of the insulation at the back: | 40 mm (MS) |
| Thickness of the insulation at the sides: | not existent |
| Material: | mineral rock wool, black glas fleece (MS) |
| Material of the casing: | Seewater resistant aluminium (MS) |
| Sealing material: | UV restitant silicon adhasive (MS) |

## 5.7 Limitations

| | |
|---|---|
| Maximum fluid pressure: | 1000 kPa (MS) |
| Operating fluid pressure: | 400 kPa (MS) |
| Maximum service temperature: | no declaration |
| Maximum stagnation temperature: | 184.4 °C |
| Maximum wind load: | no declaration |
| Recommended tilt angle: | 45° |
| Flow range recommendation: | no declaration (MS) |

## 5.8 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: | no (MS) |

## 5.9 Picture and cut drawing of the collector

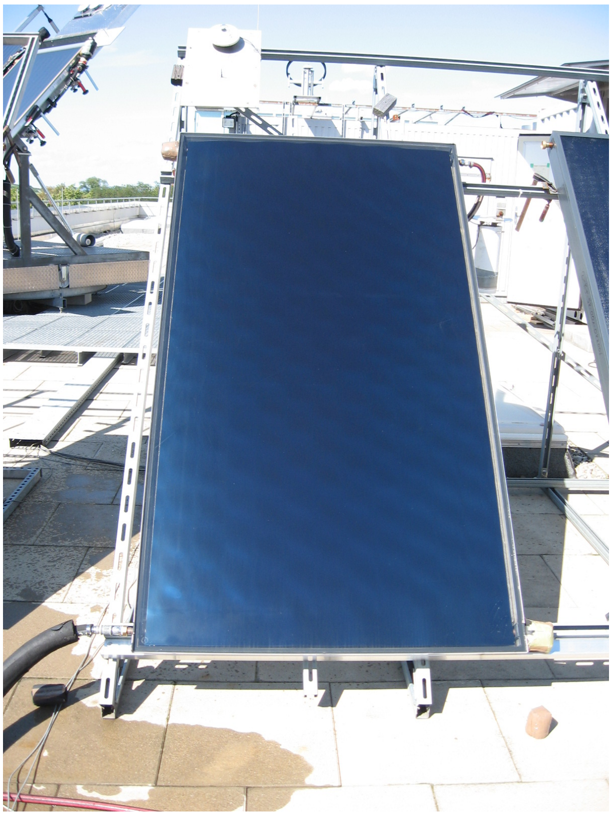

Figure 1: Picture of the collector FK 8200 N 4A Cu-Al

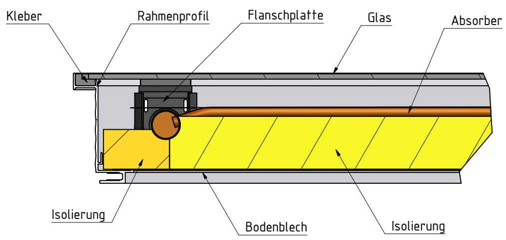


Figure 2: Cut drawing of the collector FK 8200 N 4A Cu-Al

# 6 Collector efficiency parameters

## 6.1 Test method

Outdoor, steady state according to EN 12975-2:2006 (tracker)
Thermal solar systems and components-solar collectors,Part 2: Test methods

## 6.2 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:

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

(based on aperture area)

$$t_m = \frac{t_e + t_{in}}{2}$$

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 $\eta_0,\ a_{1a}$ and $a_{2a}$ have the following meaning:

$\eta_0$: Efficiency without heat losses, which means that the mean collector fluid temperature is equal to the ambient temperature:

$$t_m = t_a$$

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:

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

## 6.3 Steady stade efficiency parameters based on the aparture area and fluid mean temperature

| | |
|---|---|
| Test method: | outdoor, steady state with tracker |
| Latitude: | 48.0° |
| Longitude: | 7.8° |
| Collector tilt: | tracked between 35°and 55° |
| Collector azimuth: | tracked |
| Mean irradiation : | 997 W/m$^2$ |
| Mean wind speed: | 3 m/s |
| Mean flow rate: | 140 kg/h |
| Kind of fluid: | water |
| Date of measurement | November 2006 |

Results:
The calculated parameters are based on following areas. They are valid for the whole series.

| aperture area of 1.924 m$^2$: | absorber area of 1.840 m$^2$: |
|---|---|
| $\eta_{0a}$ = 0.759 | $\eta_{0A}$ = 0.794 |
| $a_{1a}$ = 3.480 W/m$^2$K | $a_{1A}$ = 3.639 W/m$^2$K |
| $a_{2a}$ = 0.0161 W/m$^2$K$^2$ | $a_{2A}$ = 0.0168 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 ( $\eta_{0a}$ = 0.759 +/- 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 measurement points is:
$a_{1a}$ = 3.480 +/- 0.0772 and $a_{2a}$ = 0.0161 +/- 0.00095 .

For more detailed data and the calculated efficiency curve please see annex E.2.

## 6.4 Power output per collector unit

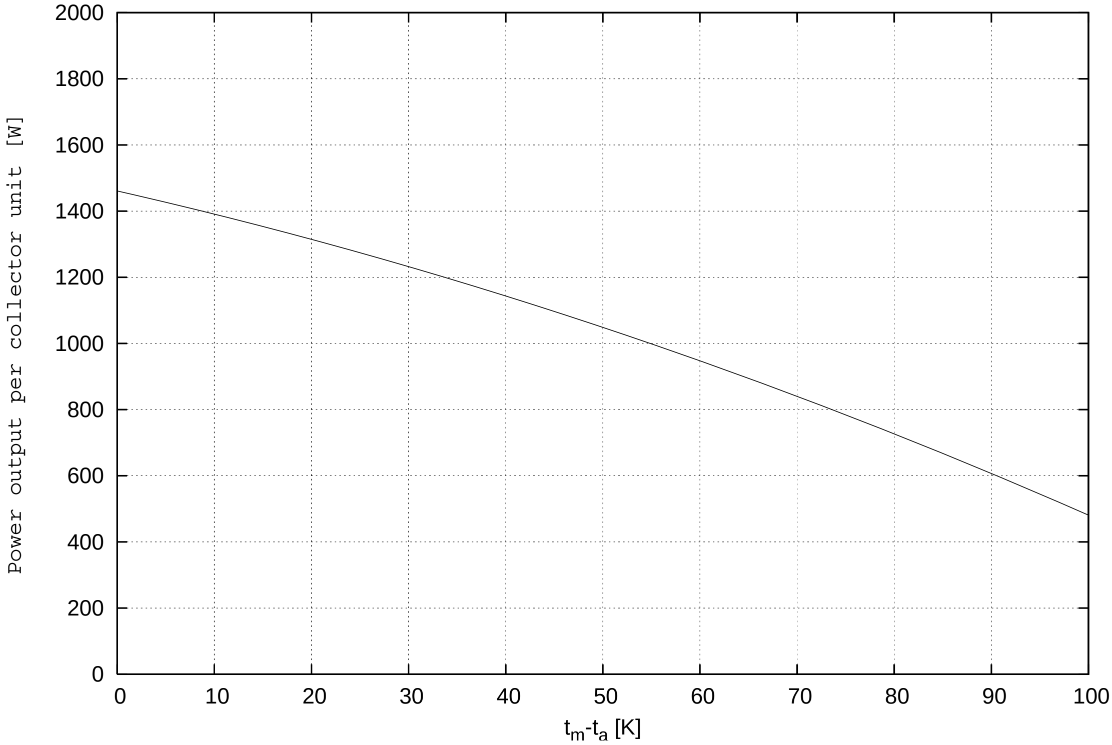


Figure 3: Power output for collector FK 8200 N 4A Cu-Al based on 1000 W/m$^2$

Power output per collector unit [W] for collector FK 8200 N 4A Cu-Al [W]:

| $t_m - t_a$ [K] | 400 [W/m$^2$] | 700 [W/m$^2$] | 1000 [W/m$^2$] |
|---|---|---|---|
| 10 | 514 | 952 | 1390 |
| 30 | 355 | 793 | 1232 |
| 50 | 172 | 610 | 1048 |

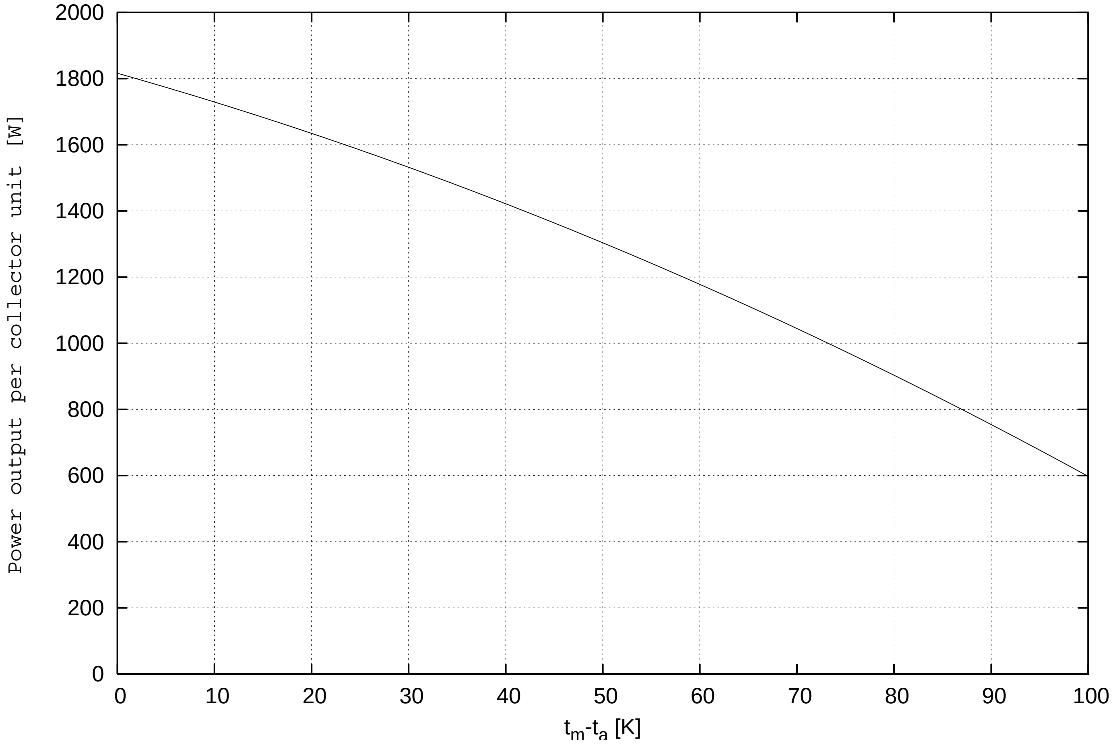


Figure 4: Power output for collector FK 8250 N 4A Cu-Al based on 1000 W/m$^2$

Power output per collector unit [W] for collector FK 8250 N 4A Cu-Al [W] :

| $t_m - t_a$ [K] | 400 [W/m$^2$] | 700 [W/m$^2$] | 1000 [W/m$^2$] |
|---|---|---|---|
| 10 | 639 | 1184 | 1728 |
| 30 | 442 | 986 | 1531 |
| 50 | 214 | 758 | 1303 |

The power output per collector unit can be calculated for other collectors of this series according to the follwoing procedure:

$$P = P_{ref} * \frac{A_a}{A_{a,ref}}$$

with:

| | |
|---|---|
| $P$ | = Collector output for a different collector of the series |
| $P_{ref}$ | = Collector output for collector FK 8200 N 4A Cu-Al , (values see table) |
| $A_a$ | = Aperture area of a different collector of the series |
| $A_{a,ref}$ | = Aperture area of collector FK 8200 N 4A Cu-Al |

## 7 Incidence angle modifier IAM

The IAM (= Incidence Angle Modifier) is a correction factor representing how the angle of incident radiation affects the performance of a collector.

The IAM of flat plate collector is assumed as rotation-symmetric. Therefor the thermal performance of the collector is only depending on the angle between the incident radiation and the normal of the collector plane.

| $\theta$: | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_\theta$: | **1.00** | 1.00 | 0,99 | 0.98 | 0.95 | **0.899** | 0.81 | 0.66 | 0.41 | 0.00 |

Table 2: Measured **(bold)** and calculated IAM data for FK 8200 N 4A Cu-Al

The IAM was measured for one angle ($\theta$ = 50°). All other angles for the IAM in table 2 were calculated according to Ambrosetti [1](equation 7).

$$K_\theta = 1 - [tan\frac{\theta}{2}]^{\frac{1}{r}} \tag{3}$$

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

# 8 Pressure drop

The measurement of the pressure drop $\Delta p$ was carried out with water as fluid up to a flow rate of 969 kg/h.The inlet temperature of the water was 20°C. The measurement has been carried out up to the flow rate 969 kg/h. The reason for the high number of measurement points at a low flow rate is given by EN 12975-2:2006. Five measurements of different flow rates in the range of 18 kg/h m$^2$ to 108 kg/h m$^2$ are necessary. The measurements were performed up to a much higher value to increase the accuracy of the parameters. Also, these flow rates are closer to flow rates occuring in collector fields.

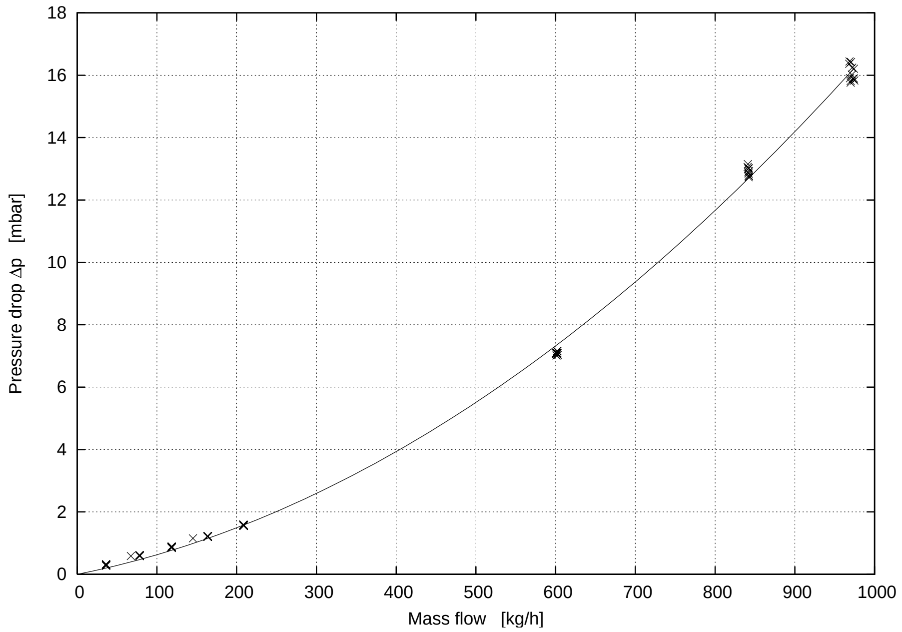


Figure 5: Measured pressure drop of the collector

The pressure drop $\Delta p$ in mbar can be described by the follwing function of the mass flow x in kg/h:

$$\Delta p = 0.004 \; * x + 1.187 * 10^{-5} \; * x^2$$

Example values from fitted curve:

| Mass flow [kg/h] | Pressure drop $\Delta p$ [mbar] |
|---|---|
| 0 | 0.0 |
| 100 | 0.6 |
| 200 | 1.5 |
| 300 | 2.6 |
| 400 | 3.9 |
| 500 | 5.5 |
| 600 | 7.3 |
| 700 | 9.3 |
| 800 | 11.6 |
| 900 | 14.1 |

Table 3: Example values for $\Delta p$

## 9 Effective thermal capacity of the collector

The effective thermal capacity of the collector is calculated according to section 6.1.6.2 of EN 12975-2:2006. For the heat transfer fluid a mixture 2/1 of water/propylen glycol at a temperature of 50°C has been chosen.

Effective thermal capacity (FK 8200 N 4A Cu-Al ):

11.01 kJ/K

The effective thermal capacity per square meter is vadil for the whole series:

5.72 kJ/K $m^2$

Fraunhofer ISE

## 10 Internal pressure test

| | |
|---|---|
| Maximum pressure specified by the manufacturer: | 1000 kPa |
| Test temperature: | 10.4 °C |
| Test pressure: | 1500 kPa (1.5 times the maximum pressure) |
| Test duration: | 15 min |

Result:
During and after the test no leakage, swelling or distortion was observed or measured.

## 11 High temperature resistance test

| Method: | Outdoor testing |
|---|---|
| Collector tilt angle: | 45° |
| Average irradiance during test: | 1015 W/m$^2$ |
| Average surrounding air temperature: | 23.5°C |
| Average surrounding air speed: | < 0.5 m/s |
| Average absorber temperature: | 180.3 °C |
| Duration of test: | 1 h |

Result:
No degradation, distortion, shrinkage or outgassing was observed or measured at the collector.

## 12 Exposure test

The collector tilt angle was 45° facing south. Annex F shows all test days of the exposure test.

Result:
The number of days when the daily global irradiance was more than 14 MJ/m$^2$d was 41 . The periods when the global irradiance $G$ was higher than 850 W/m$^2$ and the surrounding air temperature $t_\text{a}$ was higher than 10 °C was 102.6 h.

The evaluation of the exposure test is described in the chapter 20 "Final inspection".

## 13 External thermal shock tests

| Test conditions | 1st test | 2nd test |
|---|---|---|
| Outdoors: | yes | yes |
| Combined with exposure test: | yes | yes |
| Combined with high temperatur resistance test: | no | no |
| Collector tilt angle: | 45° | 45° |
| Average irradiance: | 1010 W/m$^2$ | 924 W/m$^2$ |
| Average surrounding air temperature: | 22.2 °C | 15.6 °C |
| Period during which the required operating conditions were maintained prior to external thermal shock: | 1 h | 1 h |
| Flowrate of water spray: | 0.05 l/m$^2$ s | 0.05 l/m$^2$ s |
| Temperature of water spray: | 16.8 °C | 17.6 °C |
| Duration of water spray: | 15 min | 15 min |
| Absorber temperature immediately prior to water spray: | 183.0 °C | 181.0 °C |

Result:
No cracking, distortion, condensation or water penetration was observed or measured at the collector.

## 14 Rain penetration test

| | |
|---|---|
| Collector mounted on: | Open frame |
| Method to keep the absorber warm: | Exposure of collector to solar radiation |
| Flowrate of water spray: | 0.05 l/m$^2$ s |
| Duration of water spray: | 4 h |

Result:
No water penetration was observed or measured at the collector.

## 15 Freeze resistance test

The freeze resistance test is not relevant, because the manufacturer suggestst a application of the collector only with a freeze resistance fluid.

## 16 Internal thermal shock tests

| Test conditions | 1st test | 2nd test |
|---|---|---|
| Outdoors: | yes | yes |
| Combined with exposure test: | yes | yes |
| Combined with high temperature resistance test: | no | no |
| Collector tilt angle: | 45° | 45° |
| Average irradiance: | 910 W/m$^2$ | 932 W/m$^2$ |
| Average surrounding air temperature: | 21.5 °C | 14.2 °C |
| Period during which the required operating conditions were maintained prior to internal thermal shock: | 1 h | 1 h |
| Flowrate of heat transfer fluid: | 0.02 l/m$^2$ s | 0.02 l/m$^2$ s |
| Temperature of heat transfer fluid: | 20.2 °C | 15.4 °C |
| Duration of heat transfer fluid flow: | 5 min | 5 min |
| Absorber temperature immediately prior to heat transfer fluid flow: | 168.0 °C | 158.1 °C |

No cracking, distortion or condensation was observed or measured at the collector.

## 17 Internal pressure test (retest)

| Maximum pressure specified by the manufacturer: | 1000 kPa |
|---|---|
| Test temperature: | 9.6 °C |
| Test pressure: | 1500 kPa (1.5 times the maximum pressure) |
| Test duration: | 15 min |

Result:
During and after the test no leakage, swelling or distortion was observed or measured.

## 18 Mechanical load test

### 18.1 Positive pressure test of the collector cover

The positive pressure (according to a positive pressure load caused by snow or wind) was increased in steps of 250 Pa up to the maximum pressure load.

| | |
|---|---|
| Method used to apply pressure: | suction cups, pressed |
| Maximum pressure load: | 1000 Pa |

Result:
During and after the test no damage at the cover of the collector was observed.

### 18.2 Negative pressure test of fixings between the cover and the collector box

The negative pressure (according to a negative pressure load caused by wind) was increased in steps of 250 Pa up to the maximum pressure load.

| | |
|---|---|
| Method used to apply pressure: | suction cups |
| Maximum pressure load: | 1000 Pa |

Result:
During and after the test no damage at the cover or at the cover fixings of the collector was observed.

### 18.3 Negative pressure test of mountings

The negative pressure (according to a negative pressure load caused by wind) was increased in steps of 250 Pa up to the maximum pressure load.

| | |
|---|---|
| Method used to apply pressure: | suction cups |
| Maximum pressure load: | 1000 Pa |

Result:
During and after the test no damage at the collector mounting fixtures or fixing points was observed.

## 19 Stagnation temperature

The stagnation temperature was measured outdoors. The measured data are shown in the table below. To determine the stagnation temperature, these data were extrapolated to an irradiance of 1000 W/m$^2$ and an ambient temperatur of 30 °C. The calculation is as follows:

$$t_{\text{s}} = t_{\text{as}} + \frac{G_{\text{s}}}{G_{\text{m}}} * (t_{\text{sm}} - t_{\text{am}}) \tag{4}$$

$t_{\text{s}}$: Stagnation temperature
$t_{\text{as}}$: 30 °C
$G_{\text{s}}$: 1000 W/m$^2$
$G_{\text{m}}$: Solar irradiance on collector plane
$t_{\text{sm}}$: Absorber temperature
$t_{\text{am}}$: Surrounding air temperature

| Measurement | Irradiance | Surrounding air temperature | Absorber temperature |
|---|---|---|---|
| | [W/m$^2$] | [°C] | [°C] |
| 1 | 999 | 26.8 | 180.8 |
| 2 | 992 | 27.1 | 180.3 |
| 3 | 965 | 28.3 | 176.9 |
| 4 | 959 | 28.6 | 176.7 |
| 5 | 967 | 27.6 | 177.7 |

The resulting stagnation temperature is:

184.4 °C

# 20 Final inspection

The following table shows an overview of the result of the final inspection.

| 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

# 21 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

## 22 Summary statement

The measurements were carried out from April 2006 - November 2006 .

No problems or distinctive observations occured during the measurements.

## 23 Annotation to the test report

The results described in this test report refer to the test collector. They are also valid for the whole collector series. It is not allowed to make extract copies of this test report.

Test report: KTB Nr. 2006-39-a-en

Freiburg, 31st January 2012
Fraunhofer-Institute for Solar Energy Systems ISE

| Dipl.-Ing. (FH) K. Kramer | Dipl.-Ing. (FH) S. Mehnert |
|---|---|
| Director of the PZTS | Deputy Director of the PZTS |

# A Drawing of absorber layout FK8200 N 4 A Cu-Al-P

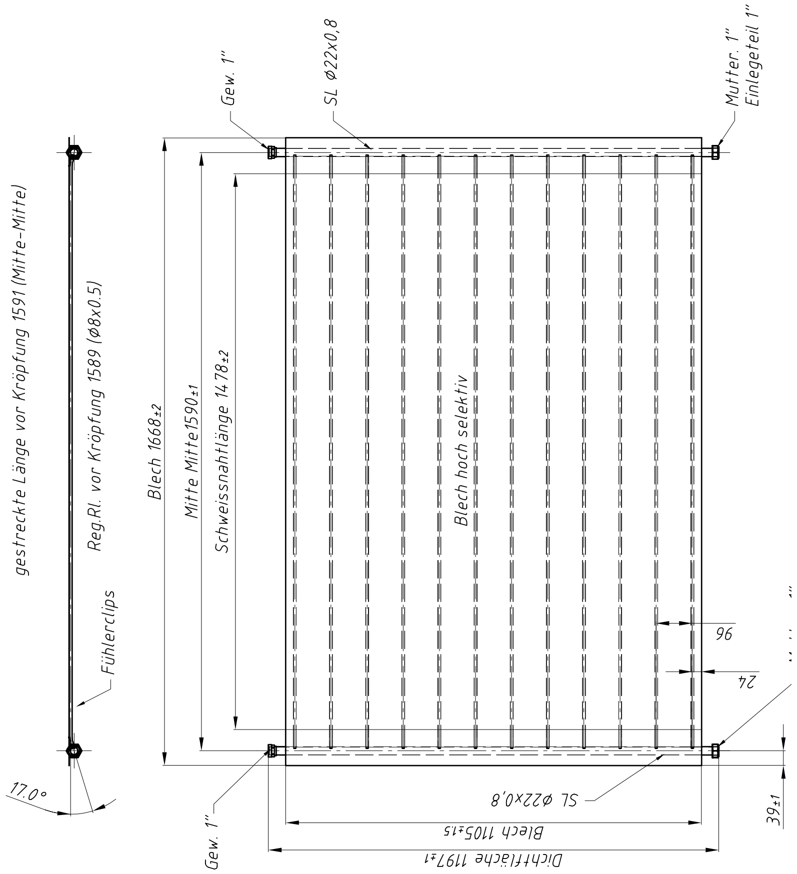


Figure 6: Drawing of absorber layout FK 8200 N 4A Cu-Al

## B Drawing of absorber layout FK8250 N 4 A Cu-Al-P

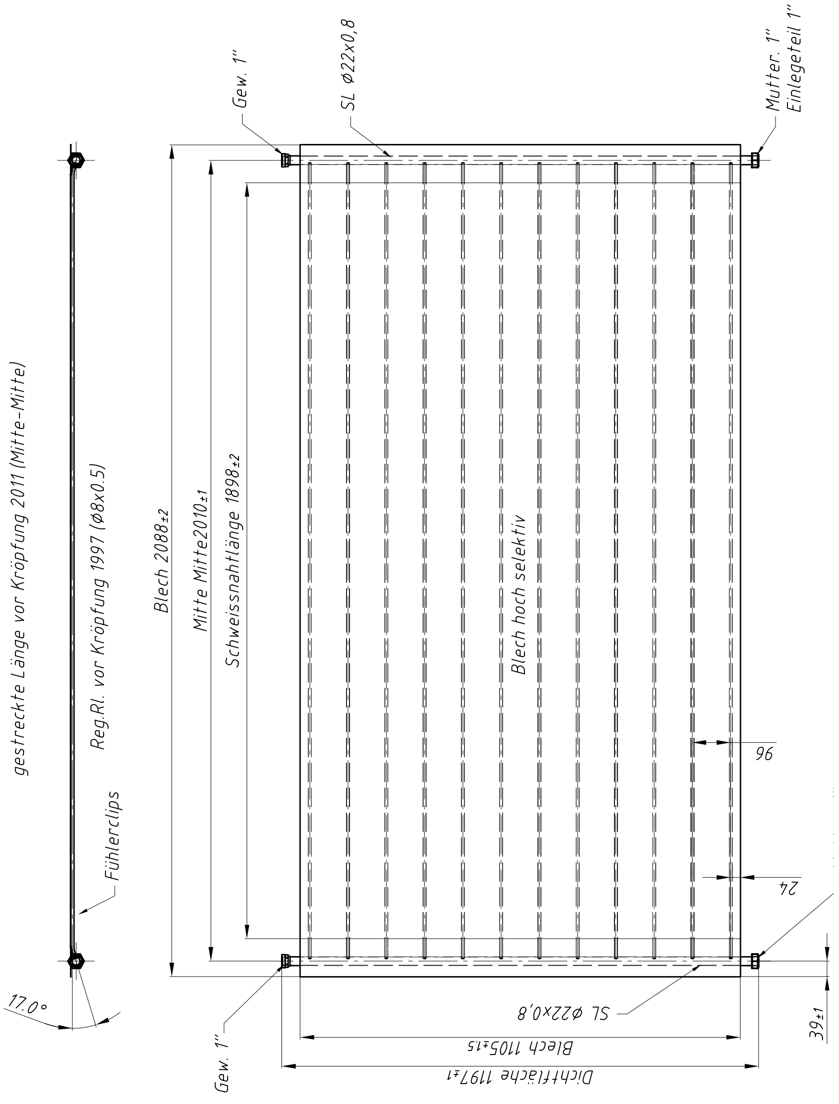


Figure 7: Drawing of absorber layout FK 8250 N 4A Cu-Al

# C Drawing of absorber layout FK8200 L 2 A Cu-Al-P

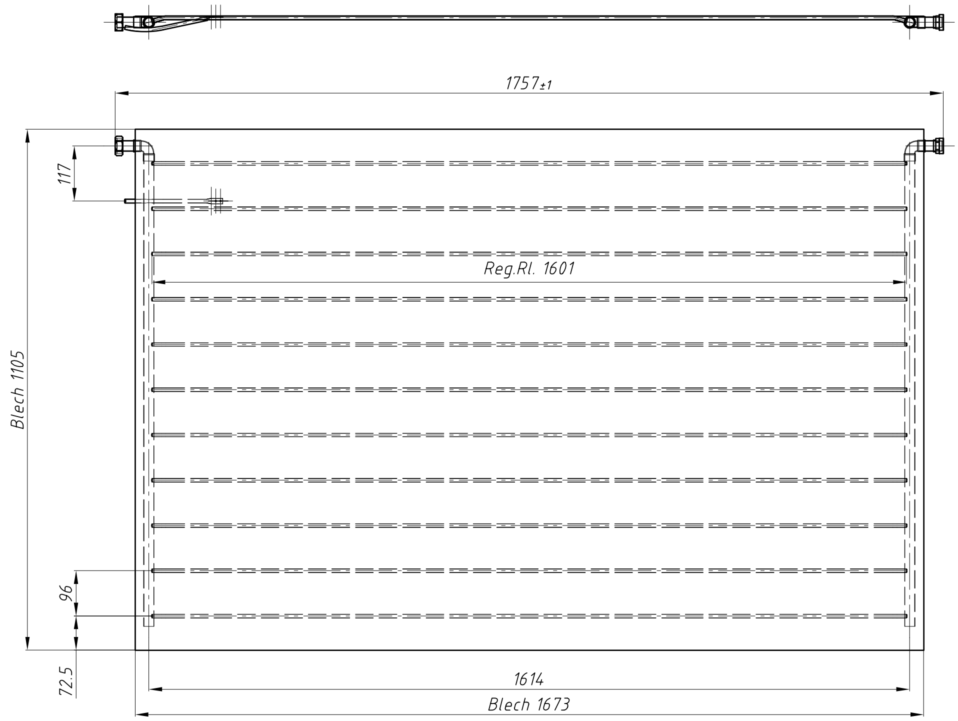


Figure 8: Drawing of absorber layout FK 8200 L 2A Cu-Al

## D Drawing of absorber layout FK8250 L 2 A Cu-Al-P

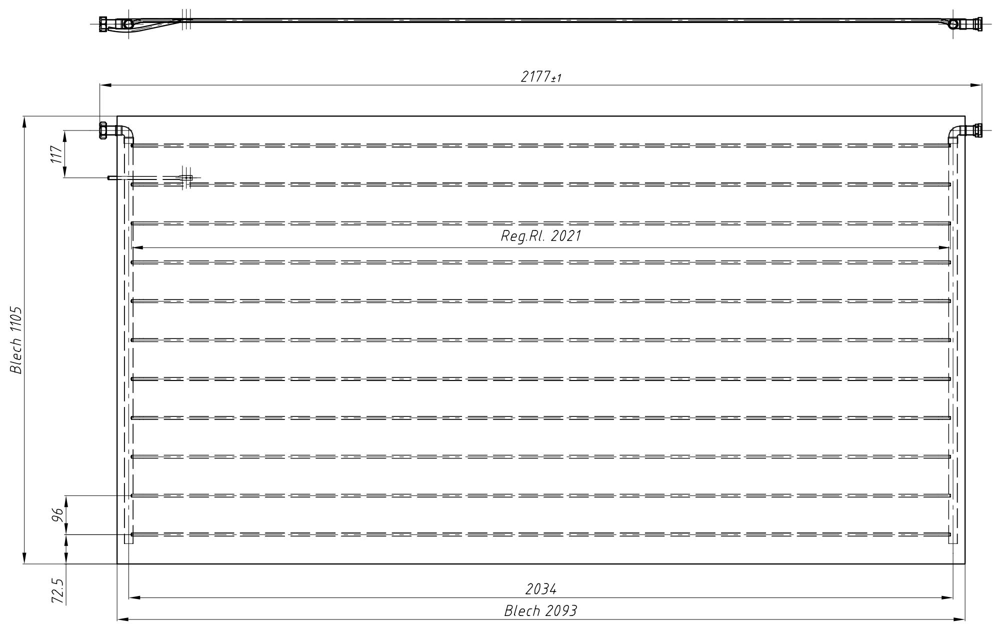


Figure 9: Drawing of absorber layout FK 8250 L 2A Cu-Al

# E Efficiency curve and measurement points

## E.1 Measured data for efficiency curve

| [W/m$^2$] | [-] | [kg/h] | [°C] | [°C] | [K] | [°C] | [°C] | [K] | [K m$^2$/W] | [-] |
|---|---|---|---|---|---|---|---|---|---|---|
| 998 | 0.17 | 132.7 | 15.61 | 25.05 | 9.44 | 20.33 | 20.05 | 0.28 | 0.0003 | 0.758 |
| 987 | 0.18 | 132.7 | 15.58 | 24.91 | 9.33 | 20.25 | 19.67 | 0.58 | 0.0006 | 0.758 |
| 984 | 0.17 | 132.6 | 15.57 | 24.90 | 9.33 | 20.24 | 20.38 | -0.14 | -0.0001 | 0.760 |
| 983 | 0.16 | 132.6 | 15.58 | 24.94 | 9.36 | 20.26 | 21.23 | -0.97 | -0.0010 | 0.763 |
| 989 | 0.16 | 147.8 | 34.93 | 42.23 | 7.29 | 38.58 | 13.08 | 25.50 | 0.0258 | 0.658 |
| 988 | 0.16 | 147.8 | 34.94 | 42.24 | 7.30 | 38.59 | 13.17 | 25.42 | 0.0257 | 0.659 |
| 995 | 0.16 | 147.8 | 34.96 | 42.33 | 7.36 | 38.65 | 13.54 | 25.10 | 0.0252 | 0.660 |
| 1000 | 0.16 | 147.8 | 34.95 | 42.35 | 7.40 | 38.65 | 13.23 | 25.42 | 0.0254 | 0.660 |
| 985 | 0.14 | 139.1 | 63.01 | 69.47 | 6.46 | 66.24 | 17.76 | 48.48 | 0.0492 | 0.552 |
| 987 | 0.14 | 139.0 | 63.04 | 69.54 | 6.50 | 66.29 | 17.98 | 48.31 | 0.0490 | 0.554 |
| 990 | 0.14 | 139.1 | 63.04 | 69.56 | 6.52 | 66.30 | 18.19 | 48.11 | 0.0486 | 0.553 |
| 995 | 0.14 | 139.2 | 63.07 | 69.63 | 6.56 | 66.35 | 18.93 | 47.41 | 0.0477 | 0.555 |
| 997 | 0.19 | 139.2 | 91.06 | 95.76 | 4.70 | 93.41 | 17.99 | 75.43 | 0.0756 | 0.399 |
| 1002 | 0.19 | 139.2 | 91.10 | 95.86 | 4.77 | 93.48 | 17.92 | 75.56 | 0.0754 | 0.402 |
| 1009 | 0.18 | 139.1 | 91.07 | 95.95 | 4.88 | 93.51 | 18.07 | 75.44 | 0.0748 | 0.409 |
| 1010 | 0.18 | 139.1 | 91.06 | 95.97 | 4.91 | 93.51 | 17.86 | 75.65 | 0.0749 | 0.411 |
| 1017 | 0.18 | 139.2 | 91.09 | 96.04 | 4.95 | 93.56 | 18.41 | 75.15 | 0.0739 | 0.411 |
| 1021 | 0.17 | 139.2 | 91.08 | 96.15 | 5.07 | 93.61 | 18.62 | 74.99 | 0.0734 | 0.420 |

Table 4: Daten der am Außenprüfstand ermittelten Wirkungsgradpunkte

## E.2 Efficiency curve

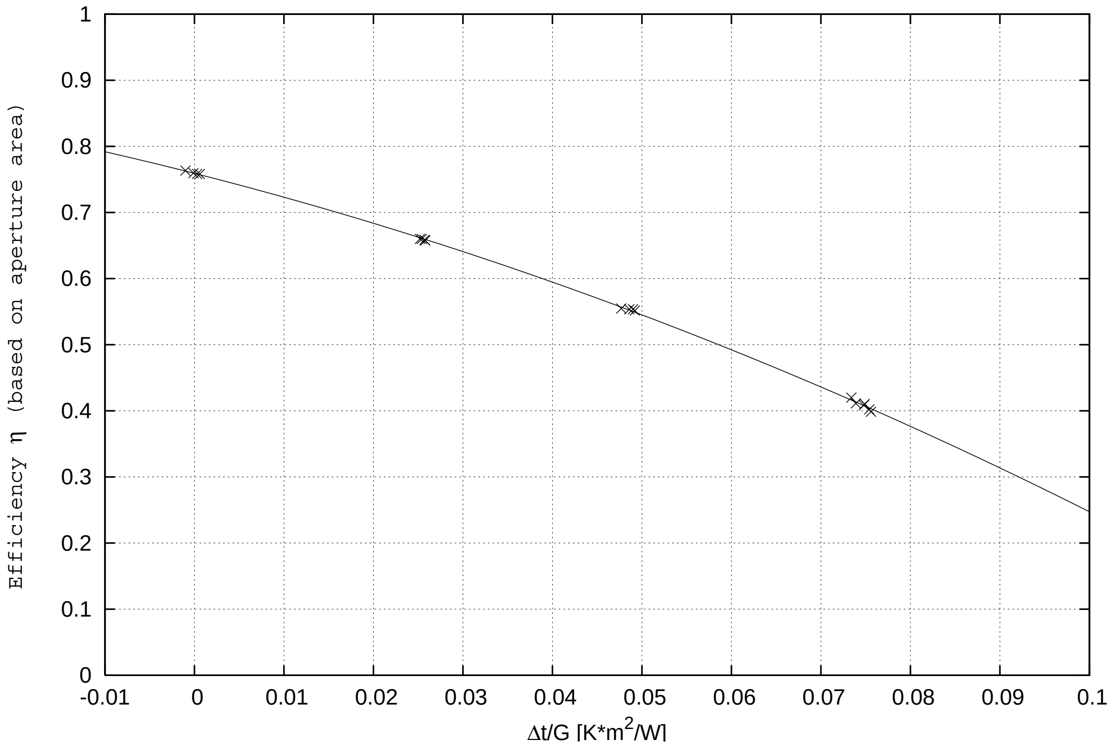


Figure 10: Efficiency curve with measurement points based on aperture area 1.924 m$^2$

Results:

The calculated parameters are based on following areas:

| aperture area of 1.924 m$^2$: | absorber area of 1.840 m$^2$: |
|---|---|
| $\eta_{0a}$ = 0.759 | $\eta_{0A}$ = 0.794 |
| $a_{1a}$ = 3.480 W/m$^2$K | $a_{1A}$ = 3.639 W/m$^2$K |
| $a_{2a}$ = 0.0161 W/m$^2$K$^2$ | $a_{2A}$ = 0.0168 W/m$^2$K$^2$ |

## E.3 Efficiency curve for the determined coefficients and for an assumed irradiation of 800 W/m$^2$ based on aperture area

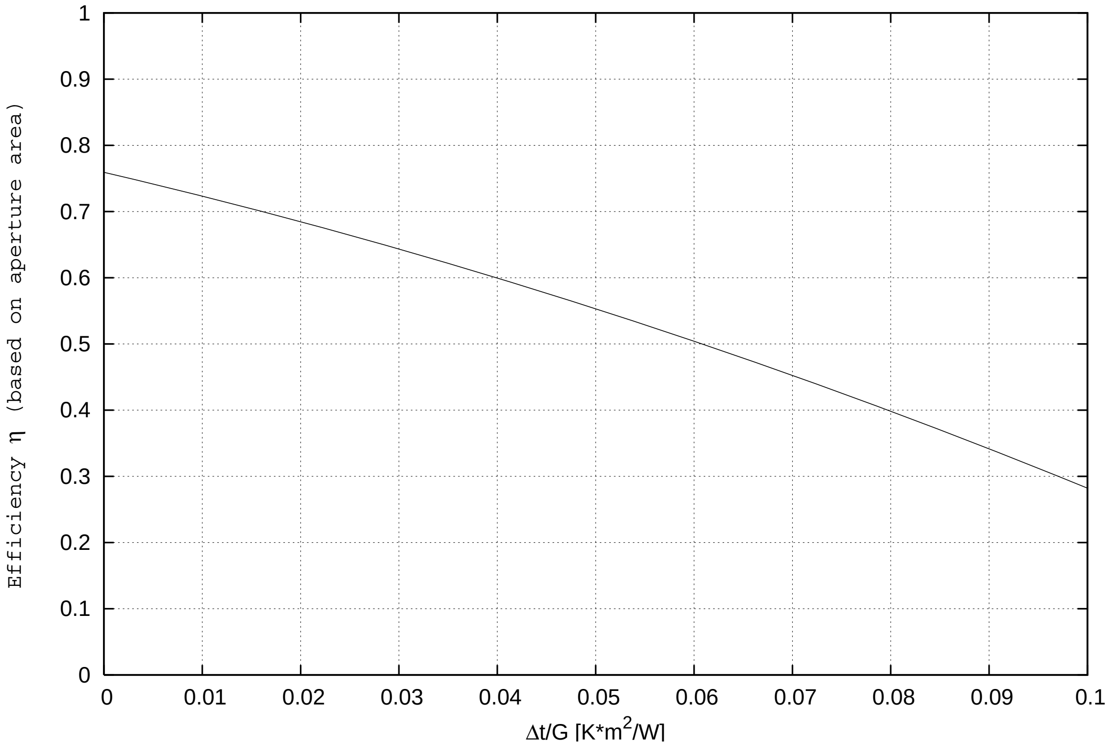


Figure 11: Efficiency curve scaled to 800 W/m$^2$ based on aperture area 1.924 m$^2$

The calculated parameters are based on following areas:

| aperture area: | absorber area: |
|---|---|
| $\eta_{0.05a}$ = 0.553 | $\eta_{0.05A}$ = 0.578 |

$\eta_{0.05}$ is the efficiency of the collector for typical conditions of solar domestic hot water systems:
irradiation of 800 W/m$^2$,
ambient temperature of 20 °C
mean collector temperture of 60 °C.

# F Data of the exposure test

| | |
|---|---|
| $H$: | daily global irradiation |
| $valid\ period$: | periods when the global irradiance $G$ is higher than 850 W/m$^2$ and the surrounding air temperature $t_a$ is higher than 10 °C |
| $t_a$: | surrounding air temperature |
| $rain$: | daily rain [mm] |

| $Date$ | $H$ [MJ/m$^2$] | $valid\ period$ [h] | $t_a$ [°C] | $rain$ [mm] |
|---|---|---|---|---|
| 20060808 | 15.5 | 0.6 | 18.0 | 1 |
| 20060809 | 22.7 | 2.7 | 18.3 | 4 |
| 20060810 | 12.2 | 0.7 | 16.0 | 11.5 |
| 20060811 | 4.6 | 0.0 | 13.7 | 9 |
| 20060812 | 16.3 | 1.8 | 14.2 | 8 |
| 20060813 | 5.8 | 0.0 | 13.1 | 12 |
| 20060814 | 6.1 | 0.0 | 13.8 | 20 |
| 20060815 | 25.1 | 4.1 | 19.3 | 6 |
| 20060816 | 17.6 | 2.0 | 19.0 | 4 |
| 20060817 | 10.8 | 0.2 | 20.2 | 15 |
| 20060818 | 25.0 | 4.4 | 20.2 | 0.5 |
| 20060819 | 20.6 | 2.9 | 20.7 | 0.5 |
| 20060820 | 18.3 | 1.6 | 18.7 | 1.5 |
| 20060821 | 12.4 | 0.5 | 18.6 | 4 |
| 20060822 | 18.6 | 2.3 | 18.0 | 0 |
| 20060823 | 26.7 | 4.1 | 18.5 | 0 |
| 20060824 | 16.1 | 1.7 | 17.8 | 2 |
| 20060825 | 13.3 | 1.4 | 17.6 | 5 |
| 20060826 | 14.5 | 1.1 | 16.2 | 6 |
| 20060827 | 11.1 | 1.0 | 16.2 | 8 |
| 20060828 | 2.4 | 0.0 | 14.6 | 14 |
| 20060829 | 5.8 | 0.0 | 12.7 | 5.7 |
| 20060830 | 11.0 | 1.0 | 12.7 | 9.8 |
| 20060831 | 26.7 | 4.0 | 16.5 | 0 |
| 20060901 | 26.6 | 4.0 | 18.4 | 0 |
| 20060902 | 15.3 | 1.5 | 21.1 | 0 |
| 20060903 | 7.3 | 0.3 | 22.0 | 0 |
| 20060904 | 16.1 | 1.1 | 24.2 | 0 |
| 20060905 | 25.2 | 3.8 | 22.8 | 0 |
| 20060906 | 14.1 | 1.0 | 20.8 | 0 |
| 20060907 | 20.9 | 3.1 | 21.8 | 11.8 |
| 20060908 | 27.0 | 4.3 | 16.8 | 0 |
| 20060909 | 26.6 | 4.0 | 16.7 | 0 |
| 20060910 | 16.6 | 0.6 | 20.3 | 1 |

Continuation, see next page:

| *Date* | *H* [MJ/m$^2$] | *valid period* [h] | $t_a$ [°C] | *rain* [mm] |
|---|---|---|---|---|
| 20060911 | 19.5 | 0.5 | 22.2 | 1 |
| 20060912 | 20.4 | 2.4 | 21.9 | 0 |
| 20060913 | 24.1 | 3.1 | 21.6 | 0 |
| 20060914 | 8.4 | 0.0 | 19.5 | 0 |
| 20060915 | 3.0 | 0.0 | 16.8 | 0 |
| 20060916 | 9.0 | 0.2 | 17.4 | 0 |
| 20060917 | 1.1 | 0.0 | 16.3 | 35 |
| 20060918 | 2.2 | 0.0 | 15.8 | 28 |
| 20060919 | 12.2 | 1.3 | 17.9 | 0 |
| 20060920 | 23.4 | 3.0 | 18.2 | 0 |
| 20060921 | 24.8 | 3.6 | 19.2 | 0 |
| 20060922 | 23.1 | 3.3 | 19.6 | 0 |
| 20060923 | 19.4 | 0.6 | 20.0 | 0 |
| 20060924 | 15.3 | 0.6 | 19.9 | 0 |
| 20060925 | 1.4 | 0.0 | 14.8 | 0 |
| 20060926 | 5.9 | 0.2 | 14.5 | 0 |
| 20060927 | 14.5 | 0.6 | 15.6 | 0 |
| 20060928 | 17.2 | 1.6 | 15.4 | 0 |
| 20060929 | 21.3 | 2.7 | 18.1 | 42 |
| 20060930 | 14.8 | 1.8 | 18.2 | 0 |
| 20061001 | 3.5 | 0.0 | 17.3 | 0 |
| 20061002 | 7.3 | 0.0 | 18.1 | 0 |
| 20061003 | 1.3 | 0.0 | 15.0 | 0 |
| 20061004 | 9.3 | 0.1 | 12.7 | 0 |
| 20061005 | 23.1 | 4.0 | 13.6 | 35 |
| 20061006 | 8.6 | 0.5 | 15.8 | 0 |
| 20061007 | 12.1 | 1.2 | 14.6 | 0 |
| 20061008 | 23.7 | 2.8 | 12.3 | 0 |
| 20061009 | 21.7 | 2.3 | 14.6 | 10 |
| 20061010 | 16.7 | 0.3 | 14.8 | 0.5 |
| 20061011 | 14.1 | 0.1 | 14.7 | 0 |
| 20061012 | 19.3 | 0.8 | 16.5 | 0 |
| 20061013 | 12.1 | 0.2 | 14.1 | 0 |
| 20061014 | 2.2 | 0.0 | 12.8 | 0 |
| 20061015 | 10.0 | 0.1 | 12.0 | 0 |
| 20061016 | 2.7 | 0.0 | 8.5 | 0 |
| 20061017 | 19.1 | 2.9 | 10.6 | 0 |
| 20061018 | 8.7 | 0.0 | 12.2 | 0 |
| 20061019 | 7.9 | 0.1 | 13.8 | 1 |
| 20061020 | 16.2 | 2.8 | 16.4 | 0 |
| 20061021 | 9.9 | 0.6 | 16.3 | 0 |
| 20061022 | 19.1 | 0.4 | 17.8 | 5 |
| 20061023 | 1.9 | 0.0 | 16.5 | 22 |

Continuation, see next page:

| *Date* | *H* [MJ/m$^2$] | *valid period* [h] | $t_a$ [°C] | *rain* [mm] |
|---|---|---|---|---|
| 20061024 | 11.3 | 0.4 | 16.4 | 0 |
| 20061025 | 7.9 | 0.0 | 12.1 | 0 |
| 20061026 | 20.0 | 1.6 | 16.8 | 0 |
| 20061027 | 3.5 | 0.0 | 19.7 | 0 |
| 20061028 | 7.0 | 0.3 | 16.2 | 0 |
| 20061029 | 1.3 | 0.0 | 15.4 | 5 |
| 20061030 | 16.2 | 1.6 | 11.2 | 0 |
| 20061031 | 8.3 | 0.1 | 12.7 | 1.5 |
| 20061101 | 10.7 | 0.8 | 9.6 | 0 |
| 20061102 | 20.3 | 0.0 | 4.2 | 0 |
| 20061103 | 10.1 | 0.0 | 3.7 | 0 |
| 20061104 | 14.9 | 0.1 | 5.0 | 0 |
| 20061105 | 9.2 | 0.0 | 4.1 | 0 |
| 20061106 | 16.6 | 0.2 | 5.2 | 0 |
| 20061107 | 17.4 | 0.8 | 5.3 | 0 |
| 20061108 | 3.4 | 0.0 | 12.5 | 0 |
| 20061109 | 1.9 | 0.0 | 12.7 | 1 |
| 20061110 | 16.8 | 0.1 | 6.1 | 0 |
| 20061111 | 1.0 | 0.0 | 8.0 | 4.5 |
| 20061112 | 5.1 | 0.0 | 8.8 | 4.5 |
| 20061113 | 2.3 | 0.0 | 9.1 | 1 |