



Fraunhofer Institut
Solare Energiesysteme

Test Report: KTB Nr. 2007-45-en

Efficiency test according to EN 12975-2:2006

for:

SUNPOWER SOLAR WATER HEATER CO.,LTD

Brand name:

SPA-H-47/1500-20

Responsible for testing:

Dipl.-Ing. (FH) K. Kramer

Date:

15th November 2007

Address:

Fraunhofer-Institute for Solar Energy Systems ISE

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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

The efficiency tests have performed passed according to EN 12975-2:2006.

1.2 Collector efficiency parameters determined

Results:

The calculated parameters are based on following areas:

aperture area of 1.248 m ² :	absorber area of 1.058 m ² :
$\eta_{0a} = 0.613$	$\eta_{0A} = 0.723$
$a_{1a} = 1.3809 \text{ W/m}^2\text{K}$	$a_{1A} = 1.629 \text{ W/m}^2\text{K}$
$a_{2a} = 0.0094 \text{ W/m}^2\text{K}^2$	$a_{2A} = 0.0111 \text{ W/m}^2\text{K}^2$

1.3 Incidence angle modifier - IAM

θ :	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
$K_{\theta T}$:	1.00	1.02	1.06	1.15	1.31	1.50	1.50	1.20	0.70	0.00
$K_{\theta L}$:	1.00	1.00	0.99	0.97	0.93	0.93	0.85	0.71	0.46	0.00

Table 1: Determined IAM data for SPA-H-47/1500-20

1.4 Effective thermal capacity of the collector

Effective thermal capacity:

13.56 kJ/K

The specific, effective thermal capacity is:

10.86kJ/K m²

1.5 Schedule of tests and calculations

Test	Date	Result
Date of delivery:	21st August 2007	
Determination of collector parameters and		
Determination of IAM	8th November 2007	performed
Effective thermal capacity	determined	performed



1.6 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
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Internet: <http://www.kollektortest.de>

3 Orderer, Expeller, Manufacturer

Orderer:	VARILLA SOLAR, S.L.
Expeller:	VARILLA SOLAR, S.L. .C.I.F.: B91669747 Parque Plata Nac.630 KM 809 PAR 3B 25 41900 Camas (Sevilla) Spain Tel: 0034-902021853 Fax: E-mail: comercial@varillasolar.es
Manufacturer:	CHANGZHOU SUNPOWER SO- LAR WATER HEATER CO.,LTD 69 SOUTH AIRPORT ROAD LUOXI TOWN CHANGZHOU JIANGSU CHINA 213136 - CHANGZHOU China Tel: 0086-0519-85083311 Fax: 0086-0519-85083220 E-mail:townway@sunpower- solar.com

4 Description of the components

4.1 Collector

	(MS) = Manufacturer Specification
Type:	vacuum tube collector with heat pipe concept
Brand name:	SPA-H-47/1500-20
Serial no.:	not specified
Year of production:	2007
Number of test collectors:	1
Collector reference no. 1:	222 KT 72 001 082007 (efficiency tests)
Total area:	1.708 m * 1.466 m = 2.504 m ² (total dimensions without fittings)
Aperture area:	1.248 m ² (projected area of the inner diameter of the outer tube, calculated according EN 12975-2 (Annex I))
Absorber area:	1.058 m ² (projected area of the absorber tubes, calculated according EN 12975-2, Annex I)
Weight empty:	not specified
Heat transfer fluid:	water/propylen-glycol

4.2 Glass tubes

Material of the cover tube:	not specified
Transmission of the cover tube:	not specified
Outer diameter of the cover tube:	47 mm (MS)
Thickness of the cover tube:	1.65 mm
Outer diameter of the inner tube:	37 mm (MS)
Thickness of the inner tube:	1.65 mm
Length of the tubes:	1500 mm (MS)
Distance from tube to tube:	75 mm (MS)
Number of tubes:	20

4.3 Absorber

Construction of the absorber:	sputtered glass tube (MS)
Material of the absorber:	not specified
Kind/Brand of selective coating:	not specified
Absorptivity coefficient α :	not specified
Emissivity coefficient ε :	not specified

4.4 Contact sheets

Material of the contact sheets:	aluminium (MS)
Thickness of the contact sheets:	0.2 mm (MS)
Dimensions of the contact sheets (unwinded)	340 mm * 72 mm
Number of contact sheets per tube	8

4.5 Heat pipes

Material of the heat pipes:	copper (MS)
Number of heat pipes:	20 (MS)
Outer diameter of the heat pipes:	8 mm (MS)
Inner diameter of the heat pipes:	7.2 mm
Outer diameter of the heat pipe condensor:	13.5 mm
Inner diameter of the heat pipe condensor:	12.7mm
Length of the heat pipe condensor:	50 mm
Distance between the pipes:	75 mm (MS)

4.6 Heat pipes

Material of the header pipe:	copper (MS)
Outer diameter of the header pipe:	22 mm
Inner diameter of the header pipe:	19.4 mm
Length of the header pipe	not specified
Volume of the fluid in the header	1.1 l (MS)

4.7 Insulation and Casing

Collector dimensions	
Height, width, depth:	1.708 m; 1.466 m; 0.160 m
Thickness of the insulation at the back of the header:	55 mm
Thickness of the insulation at the front of the header:	65 mm
Insulation material:	glasswool
Material of the casing:	high-grade steel (MS)
Sealing material:	silicon (MS)

4.8 Limitations

Maximum fluid pressure:	not specified
Operating fluid pressure:	not specified
Maximum service temperature:	125 °C (MS)
Maximum stagnation temperature:	250 °C (MS)
Maximum wind load:	not specified
Recommended tilt angle:	not specified
Flow range recommendation:	not specified

4.9 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)

4.10 Picture of the collector

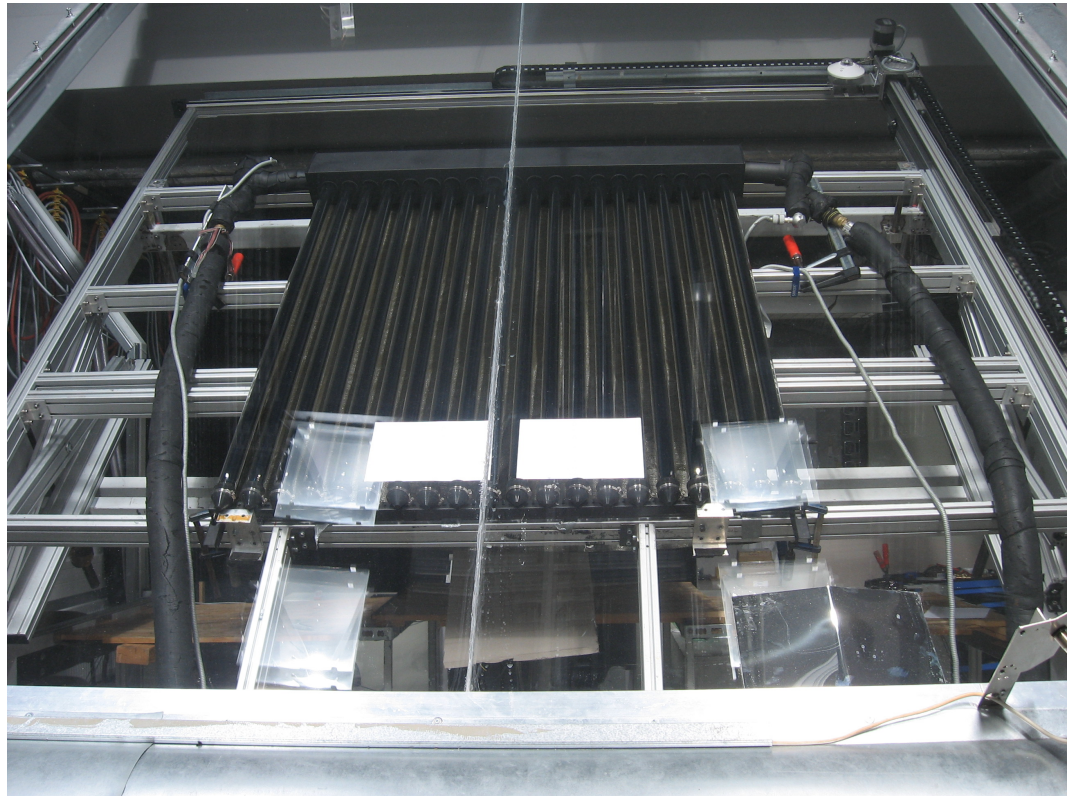


Figure 1: Picture of the collector SPA-H-47/1500-20 mounted on the test facility of Fraunhofer ISE

5 Collector efficiency parameters

5.1 Test method

Indoor with solar simulator, steady state according to EN 12975-2:2006
Thermal solar systems and components-solar collectors,
Part 2: 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)

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

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

The coefficients η_0 , a_{1a} and 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:

$$t_m = t_a$$

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

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

5.3 Efficiency parameters

Boundary conditions:

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

Test method:	indoor, steady state
Collector tilt:	45 °
Mean wind speed:	3 m/s
Kind of fluid:	Water
Mean flow rate:	90 kg/h
Mean irradiation G :	950 W/m ²

Results:

The calculated parameters are based on following areas¹:

aperture area of 1.248 m ² :	absorber area of 1.058 m ² :
$\eta_{0a} = 0.613$	$\eta_{0A} = 0.723$
$a_{1a} = 1.3809 \text{ W/m}^2\text{K}$	$a_{1A} = 1.629 \text{ W/m}^2\text{K}$
$a_{2a} = 0.0094 \text{ W/m}^2\text{K}^2$	$a_{2A} = 0.0111 \text{ W/m}^2\text{K}^2$

The determination for the standard deviation was performed according ENV 13025:1999 (GUM). Based on this calculation the standard uncertainty (k=2) of the determined efficiency points amounts 0.02. (for example $T_m - T_a = 0; \eta = 0.613 \pm 0,02$) The given uncertainty is an expanded measurement uncertainty, which is based on a measurement uncertainty of 0.01 multiplied with a expand factor of k=2, to result in an confidence level of approximately 95%.(EAL-G23, 08/96 Rev01)

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

5.4 Power output per collector unit

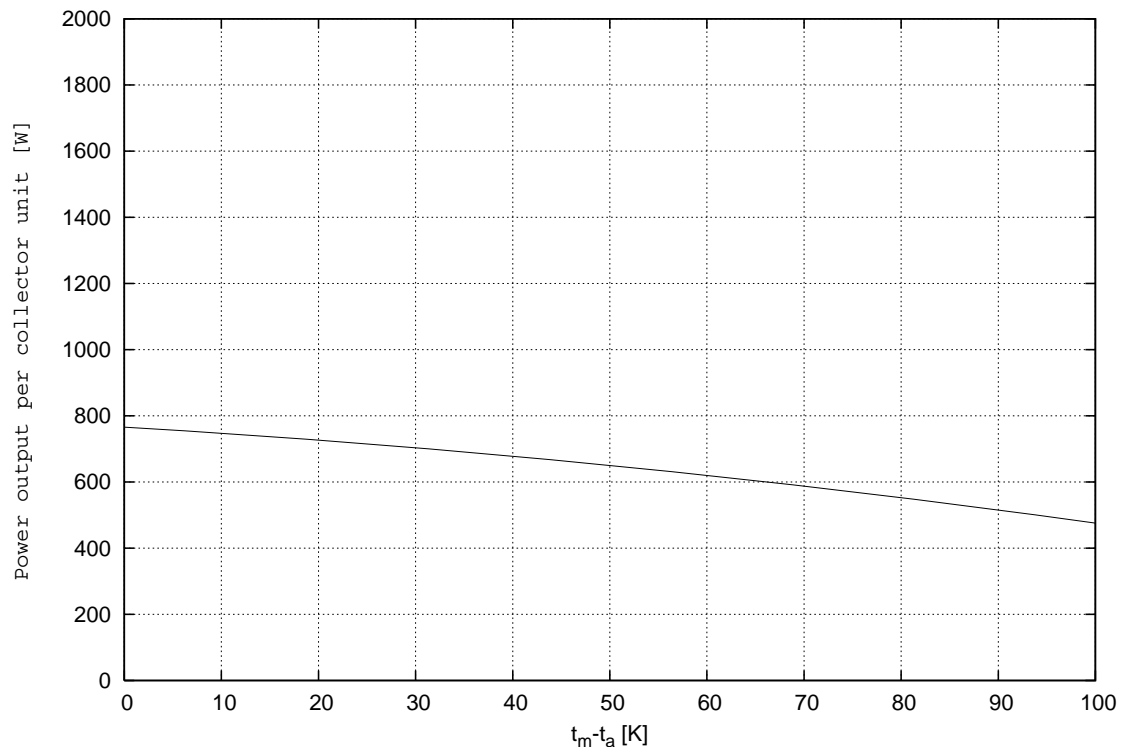


Figure 2: Power output for collector SPA-H-47/1500-20 based on 1000 W/m²

Power output per collector unit [W] for collector SPA-H-47/1500-20
(aperture area of 1.248 m²):

$t_m - t_a$ [K]	400 [W/m ²]	700 [W/m ²]	1000 [W/m ²]
10	288	517	747
30	244	473	703
50	191	420	650

6 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. Therefore the thermal performance of the collector is only depending on the angle between the incident radiation and the normal of the collector plane.

For collectors which have a direction-dependent IAM behaviour (for example vacuum tube collectors and collectors with CPC reflectors), it is necessary to measure the IAM for more than one direction, to have a proper determination of the IAM.

The complex IAM can be estimated by calculating it as the product of both separately measured incidence angle modifiers $K_{\theta L}$ and $K_{\theta T}$ of two orthogonal planes (equation 2).

$$K_{\theta} = K_{\theta L} \times K_{\theta T} \quad (2)$$

The longitudinal plane (index L) is orientated parallelly to the optical axis of the collector. The transversal plane is orientated orthogonally to the optical axis of the collector. The angles θT and θL are the projection of the incidence angle of the radiation on the transversal or longitudinal plane.

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

θ :	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
$K_{\theta T}$:	1.00	1.02	1.06	1.15	1.31	1.50	1.50	1.20	0.70	0.00
$K_{\theta L}$:	1.00	1.00	0.99	0.97	0.93	0.93	0.85	0.71	0.46	0.00

Table 2: Determined IAM data for SPA-H-47/1500-20

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 12975-2:2006. For the heat transfer fluid a mixture 2/1 of water/propylenglycol at a temperature of 50°C has been chosen.

Effective thermal capacity (SPA-H-47/1500-20):

13.56 kJ/K

The effective thermal capacity per square meter is:

10.86kJ/K m²

8 Collector identification

The documentation according EN 12975-1 chapter 7 was incomplete in the following items:

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



9 Summary statement

The measurements were carried out at 8th November 2007.

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. 2007-45-en

Freiburg, 15th November 2007

Fraunhofer-Institute for Solar Energy Systems ISE

Dipl.-Phys. M. Rommel
Head of the Test Center for
Thermal Solar Systems

Dipl.-Ing. (FH) K. Kramer
Responsible for testing
and report

A Efficiency curve

A.1 Efficiency curve with measurement points based on aperture area 1.248 m²

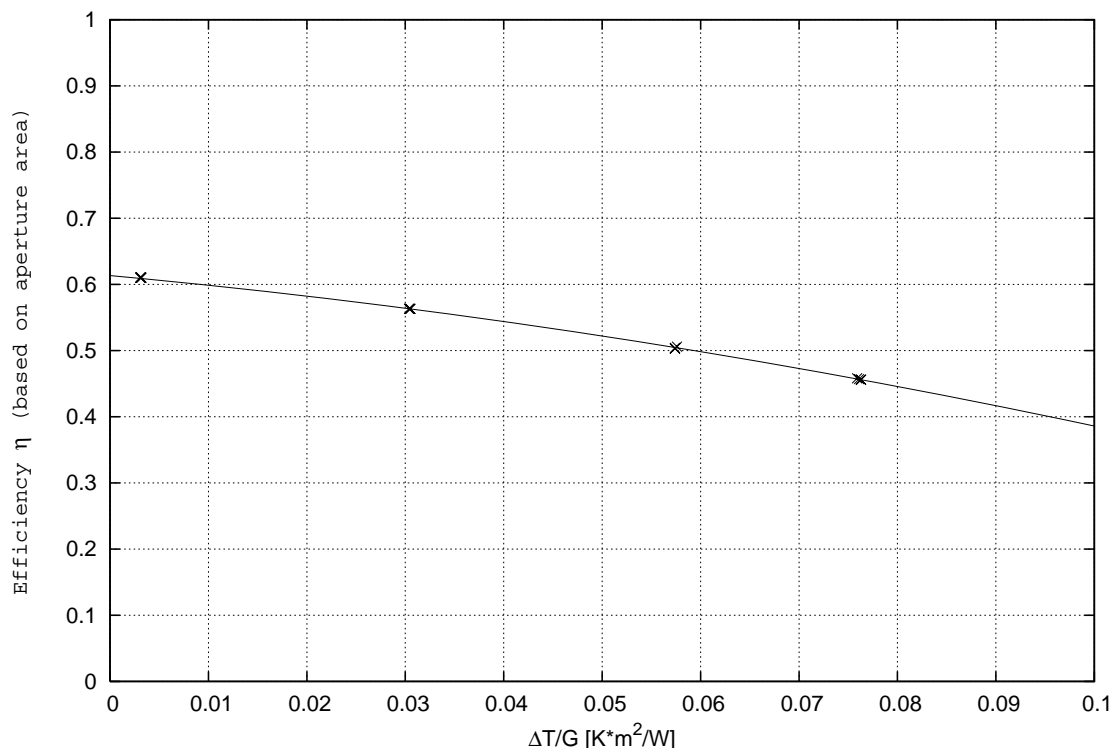


Figure 3: Efficiency curve with measurement points based on aperture area 1.248 m²

Results:

The calculated parameters are based on following areas:

aperture area of 1.248 m ² :	absorber area of 1.058 m ² :
$\eta_{0a} = 0.613$	$\eta_{0A} = 0.723$
$a_{1a} = 1.3809 \text{ W/m}^2\text{K}$	$a_{1A} = 1.629 \text{ W/m}^2\text{K}$
$a_{2a} = 0.0094 \text{ W/m}^2\text{K}^2$	$a_{2A} = 0.0111 \text{ W/m}^2\text{K}^2$

A.2 Efficiency curve for the determined coefficients and for an assumed irradiation of 800 W/m² based on aperture area

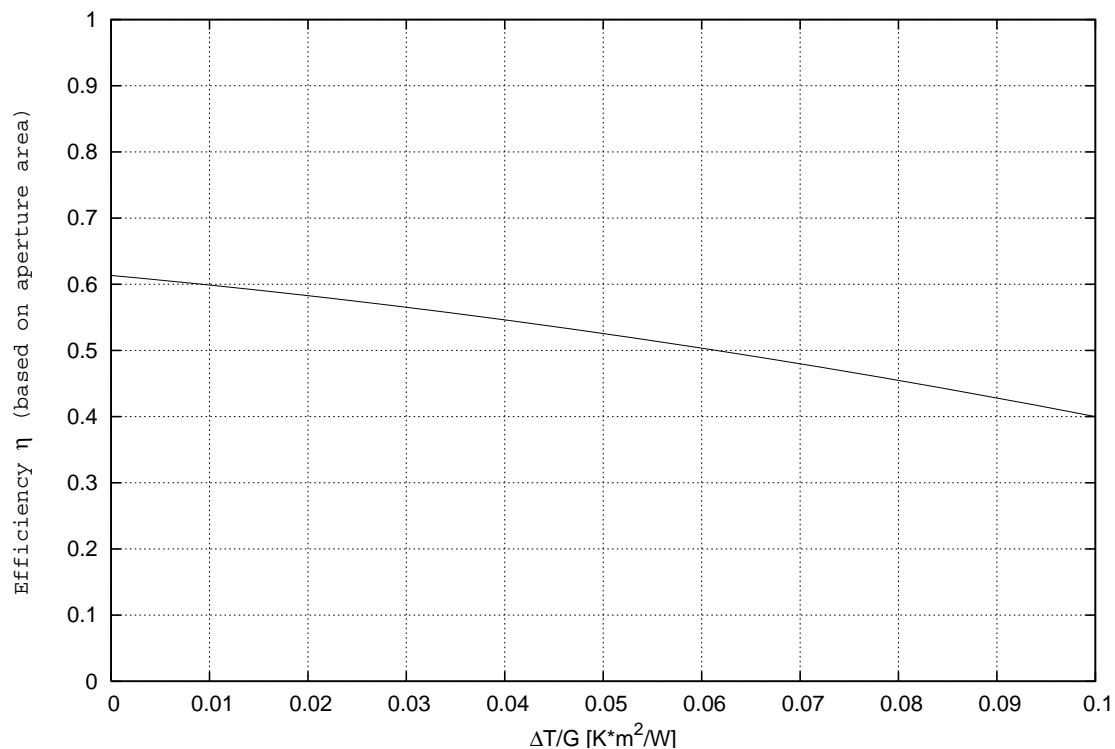


Figure 4: Efficiency curve scaled to 800 W/m² based on aperture area 1.248 m²

The calculated parameters are based on following areas:

aperture area:

$$\eta_{0.05a} = 0.525$$

absorber area:

$$\eta_{0.05A} = 0.619$$

$\eta_{0.05}$ is the efficiency of the collector for typical conditions of solar domestic hot water systems:

irradiation of 800 W/m²,

ambient temperature of 20 °C

mean collector temperature of 60 °C.

A.3 Measured data for efficiency curve

m	t_{in}	t_e	$t_e - t_{in}$	t_m	t_a	$t_m - t_a$	$(t_m - t_a)/G$	η_{a_a}
[kg/h]	[°C]	[°C]	[K]	[°C]	[°C]	[K]	[Km ² /W]	[-]
93.2	99.54	104.50	4.96	102.02	29.57	72.44	0.0763	0.456
93.1	99.59	104.54	4.96	102.06	29.61	72.45	0.0763	0.456
93.2	99.62	104.58	4.97	102.10	29.77	72.32	0.0761	0.457
93.2	99.66	104.64	4.98	102.15	30.04	72.11	0.0759	0.458
87.1	82.16	88.07	5.90	85.11	30.36	54.75	0.0576	0.506
87.1	82.13	88.00	5.87	85.06	30.49	54.57	0.0574	0.503
87.1	82.12	87.99	5.87	85.06	30.57	54.49	0.0574	0.503
87.0	82.12	88.00	5.88	85.06	30.55	54.51	0.0574	0.504
90.0	56.40	62.78	6.38	59.59	30.64	28.95	0.0305	0.563
89.8	56.39	62.79	6.39	59.59	30.62	28.97	0.0305	0.563
89.8	56.38	62.78	6.39	59.58	30.67	28.91	0.0304	0.563
89.8	56.38	62.77	6.39	59.57	30.68	28.89	0.0304	0.563
91.4	30.07	36.90	6.83	33.48	30.51	2.97	0.0031	0.611
91.4	30.03	36.85	6.82	33.44	30.42	3.02	0.0032	0.610
91.3	30.00	36.83	6.83	33.42	30.50	2.92	0.0031	0.610
91.3	29.99	36.81	6.82	33.40	30.46	2.94	0.0031	0.610
91.8	25.56	32.41	6.85	28.98	30.52	-1.54	-0.0016	0.616
91.8	25.53	32.38	6.85	28.96	30.60	-1.65	-0.0017	0.616
91.8	25.52	32.36	6.84	28.94	30.51	-1.57	-0.0017	0.616
91.9	25.51	32.37	6.86	28.94	30.57	-1.63	-0.0017	0.617
90.7	22.70	29.68	6.98	26.19	30.58	-4.39	-0.0046	0.620
90.7	22.68	29.65	6.98	26.17	30.56	-4.39	-0.0046	0.620
90.6	22.67	29.64	6.98	26.15	30.60	-4.44	-0.0047	0.619
90.7	22.66	29.64	6.97	26.15	30.46	-4.30	-0.0045	0.619
90.6	22.66	29.63	6.97	26.14	30.55	-4.41	-0.0046	0.619
90.6	22.66	29.63	6.97	26.14	30.55	-4.41	-0.0046	0.618
90.6	22.66	29.64	6.99	26.15	30.58	-4.44	-0.0047	0.620

Table 3: Data of measured efficiency points

m	t_{in}	t_e	$t_e - t_{in}$	t_m	t_a	$t_m - t_a$	$(t_m - t_a)/G$	η_{aa}
[kg/h]	[°C]	[°C]	[K]	[°C]	[°C]	[K]	[Km ² /W]	[-]
90.6	22.65	29.62	6.97	26.14	30.64	-4.50	-0.0047	0.619
90.6	22.66	29.64	6.98	26.15	30.59	-4.45	-0.0047	0.620
90.5	22.66	29.65	6.99	26.15	30.61	-4.46	-0.0047	0.619
90.5	22.66	29.64	6.99	26.15	30.67	-4.52	-0.0048	0.619
90.5	22.66	29.64	6.99	26.15	30.60	-4.45	-0.0047	0.619
90.5	22.66	29.65	6.99	26.15	30.56	-4.41	-0.0046	0.619
90.4	22.66	29.66	7.00	26.16	30.65	-4.49	-0.0047	0.620
90.6	22.66	29.64	6.98	26.15	30.56	-4.41	-0.0046	0.619
90.5	22.66	29.65	6.99	26.16	30.71	-4.55	-0.0048	0.619
90.5	22.67	29.66	6.99	26.16	30.67	-4.51	-0.0047	0.620
90.5	22.67	29.66	6.99	26.17	30.58	-4.41	-0.0046	0.620
90.5	22.67	29.66	6.99	26.16	30.67	-4.50	-0.0047	0.620
90.5	22.67	29.66	6.99	26.16	30.66	-4.50	-0.0047	0.620
90.5	22.67	29.66	6.99	26.16	30.58	-4.42	-0.0047	0.620
90.5	22.67	29.66	6.99	26.17	30.76	-4.59	-0.0048	0.620
90.5	22.67	29.67	7.00	26.17	30.61	-4.44	-0.0047	0.620
90.4	22.67	29.66	6.99	26.17	30.75	-4.58	-0.0048	0.619
90.4	22.67	29.67	7.00	26.17	30.81	-4.64	-0.0049	0.620
90.4	22.67	29.67	6.99	26.17	30.76	-4.59	-0.0048	0.620
90.5	22.68	29.67	7.00	26.18	30.84	-4.66	-0.0049	0.620
90.3	22.68	29.69	7.01	26.19	30.84	-4.65	-0.0049	0.620

Table 4: Data of measured efficiency points