Fraunhofer Institut
Solare Energiesysteme

Test Report: KTB No. 2006-27

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

for:
Himin Solar Energy Group Co., Ltd. , China

Brand Name:
HUJ 16/2.1 , HUJ 12/2.1, HUJ 16/1.8, HUJ 12/1.8, HUJ 16/1.6 and HUJ 12/1.6

Responsible for Testing:
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Date:
29th November 2006

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Accreditated according to DIN EN ISO/IEC 17025:2005

Deutscher Akkreditierungs Rat
DAR

Registration No.:
DAP-PL-3926.00

DIN CERTCO
Anerkanntes Prüflaboratorium

Contents

1 Summary

1.1 Preliminary remark

The collector test was performed with the purpose of the European quality label SolarKeymark. All relevant tests have been passed with success.

The present report is valid for the series of the collector type HUJ of the company Himin Solar Energy Group Co., Ltd. with the collectors HUJ 16/2.1 , HUJ 12/2.1, HUJ 16/1.8, HUJ 12/1.8, HUJ 16/1.6 and HUJ 12/1.6 . The tests were performed at the largest collector and at the smallest collector of the series (HUJ 16/2.1 and HUJ 12/1.6), according the rules of the SolarKeymark.

The tests were performed concidering all requirements of the standard EN 12975-1,2 : 2000 (valid version at the time of the tests) and EN 12975-1,2 : 2006 (new/present version).

1.2 Collector parameters determined

The following parameters are based on the

aperture area of 1.764 m^2:		absorber area of 1.522 m^2:	
η_{0a}	= 0.779	η_{0A}	= 0.903
a_{1a}	= 2.103 W/m^{2}K	a_{1A}	= 2.437 W/m^{2}K
a_{2a}	= 0.0107 W/m^{2}K^2	a_{2A}	= 0.0124 W/m^{2}K^2

1.3 Incidence angle modifier - IAM

IAM at θ:	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
transversal:	**1.00**	**1.02**	**1.04**	**1.12**	**1.25**	**1.45**	**1.63**	**1.60**	1.40	0.05
longitudinal:	**1.00**	1.00	1.00	1.00	0.99	**0.98**	0.94	0.83	0.58	0.00

Table 1: Measured **(bold)** and calculated IAM data for HUJ 16/2.1

1.4 Pressure drop

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

$$\Delta p = 0.0486 * x + 0.00029 * x^2$$

1.5 Effective thermal capacity of the collector

Effective thermal capacity (HUJ 16/2.1):

34,63 kJ/K

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

19,63 kJ/K m^2

1.6 Functional tests

Test	Date	Result
Date of delivery:	12th July 2005	
1st internal pressure	11th August 2005	passed
High temperature resistance	11th August 2005	passed
Exposure	10th August - 14th October 2005	passed
1st external thermal shock	17th August 2005	passed
2nd external thermal shock	8th September 2005	passed
1st internal thermal shock	11th August 2005	passed
2nd internal thermal shock	11th October 2005	passed
Rain penetration	17th August 2005	passed
Freeze resistance	-	not relevant
2nd internal pressure	27th September 2005	passed
Mechanical load	15th October	passed
Stagnation temperature	11th August - 5th September 2005	246 °C
Final inspection	17th March 2006	passed
Determination of collector parameters	13th March 2006 - 15th March 2006	passed
Determination of IAM	27th July 2005 - 09th August 2005	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
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3 Orderer, Expeller, Manufacturer

Expeller and Manufacturer:	see orderer
Orderer	Himin Solar Energy Group Co., Ltd. Hubin North Road 37 253090 Dezhou, P.R. China Tel: +86-534-2312805 Fax: +86-534-2312811-2702 E-mail: business@himin.com

4 Overview of series HUJ collectors

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

Brand name	test collector	number of tubes	length of tubes
HUJ 16/2.1	yes	16	2.1 m
HUJ 12/2.1	no	12	2.1 m
HUJ 16/1.8	no	16	1.8 m
HUJ 12/1.8	no	12	1.8 m
HUJ 16/1.6	no	16	1.6 m
HUJ 12/1.6	yes	12	1.6 m

5 Description of the Collector

	(MS) = Manufacturer Specification
Type:	Vacuum tube or evacuated tube collector with glass absorber and u-type construction
Reflector construction:	no reflector

5.1 Specific data of the largest collector of the series (HUJ 16/2.1)

Brand name:	HUJ 16/2.1
hline Serial no.:	0505201170
Year of production:	2005
Number of test collectors:	1
Collector reference no. (ISE):	2 KT 48 001 062005 (HUJ 16/2.1)
Total area:	2.290 m * 1.516 m = 3.472 m^2
Collector depth:	0.134 m
Aperture area:	0.0544 m * 2.027 m * 16 tubes = 1.764 m^2
Absorber area:	0.047 m * 2.024 m * 16 tubes = 1.522 m^2 (projected area of the absorber tubes) (MS)
Number of tubes:	16
Length of the tubes:	2100 mm (MS)
Weight empty:	68,2 kg
Volume of the fluid:	2.82 l (MS)

5.2 Specific data of the smallest collector of the series (HUJ 12/1.6)

Brand name:	HUJ 12/1.6
Serial no.:	0506060320
Year of production:	2005
Number of test collectors:	1
Collector reference no.(ISE):	2 KT 48 003 062005 (HUJ 12/1.6)
Total area:	1.790 m * 1.165 = 2.085 m^2
Collector depth:	0.134 m
Aperture area:	0.0544 m * 1.536 m * 12 tubes = 1.003 m^2
Absorber area:	0.047 m * 1.536 m * 12 tubes = 0.866 m^2 (projected area of the absorber tubes) (MS)
Number of tubes:	12
Length of the tubes:	1600 mm (MS)
Weight empty:	41.5 kg
Volume of the fluid:	1.99 l (MS)

5.3 Collector and Absorber

	(MS) = Manufacturer Specification
Material of the cover tube:	Borosilicate glass (MS)
Transmission of the cover tube:	90 % (MS)
Outer diameter of the cover tupe:	58 mm (MS)
Thickness of the cover tube:	1.8 mm (MS)
Outer diameter of the inner tube	47 mm (MS)
Thickness of the inner tube:	1.6 mm (MS)
Distance from tube to tube:	88 mm (MS)
Heat transfer fluid:	Water-glycol (MS)
Material of the absorber:	Glass (MS)
Kind/Brand of selective coating:	Graded AlN/SS- AlN/Cu on glass (MS)
Absorptivity coefficient α:	94% (MS)
Emissivity coefficient ε:	7% (MS)
Function of the absorber:	Contact sheets to the inner glass tube, connected to U-pipes
Material of the contact sheets:	Aluminium
Thickness of the contact sheets:	0.3 mm
Material of the U-pipes:	Copper (MS)
Outer U-pipe diameter:	8 mm (MS)
Inner U-pipe diameter:	6.8 mm (MS)
Material of the header pipe:	Copper (MS)
Number of header pipes:	2
Outer diameter of the header pipe:	15 mm (MS)
Inner diameter of the header pipe:	13 mm (MS)

5.4 Insulation and Casing

Medium between the inner and outer tubes of the vacuum flask:	high vacuum
Thickness of the insulation in the header:	average 20 mm
Material of the insulation in the header:	Polyurethane (MS)
Material of the casing:	Aluminium (6063T5) (MS)
Sealing material:	Silicon rubber (MS)

5.5 Limitations

Maximum pressure:	1300 kPa (MS)
Operating pressure:	600 kPa(MS)
Maximum stagnation temperature:	246 °C
Flow range recommendation:	not specified

5.6 Kind of mounting

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

5.7 Picture and assembly drawing of the collector

Figure 1: Picture of the collector HUJ 16/2.1 mounted on the test facility of Fraunhofer ISE

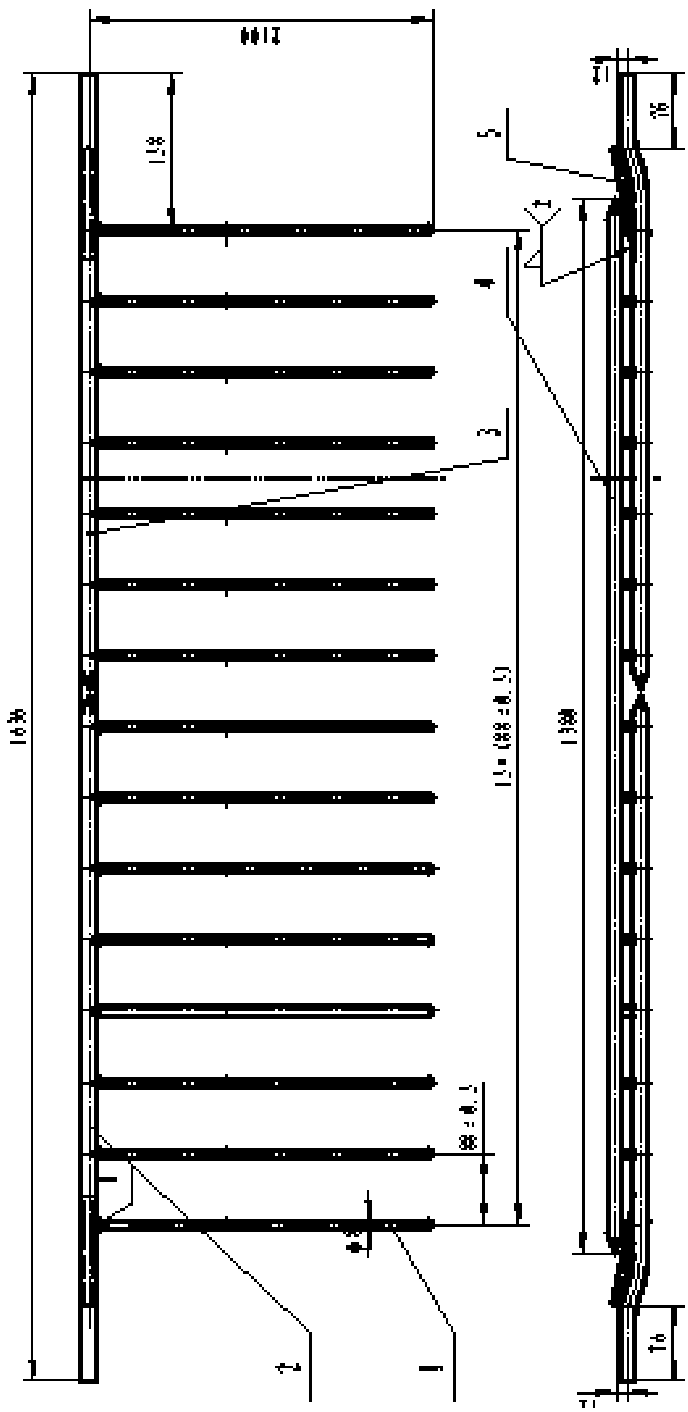

Figure 2: Drawing of the collector HUJ 16/2.1

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:

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

(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:

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

6.3 Efficiency parameters

Boundary conditions for the determination:

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 rooftiles.

Test method:	outdoor, steady state
Latitude:	48.0°
Longitude:	7.8°
Collector tilt:	tracked between 40°and 50°
Collector azimuth:	tracked
Mean irradiation :	1017 W/m^2
Mean wind speed:	3 m/s
Mean flow rate:	136 kg/h
Kind of fluid:	water
Period:	March 2006

Results:
The calculated parameters are based on following areas:

aperture area (1.764 m^2):	absorber area (1.522 m^2):
η_{0a} = 0.779	η_{0A} = 0.903
a_{1a} = 2.103 W/m^{2}K	a_{1A} = 2.437 W/m^{2}K
a_{2a} = 0.0107 W/m^{2}K^2	a_{2A} = 0.0124 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} = 0.779 +/- 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} = 2.103 +/- 0.085 and a_{2a} = 0.0107 +/- 0.0009 .

6.4 Power output per collector unit

The power output per collector unit will be documented for the larges collector of the series HUJ 16/2.1 with the highest output per collector unit and for the smallest collector of the series HUJ 12/1.6 with the lowest output per collector unit.

Power output per collector unit [W] for collector HUJ 16/2.1 (aperture area of 1.764 m^2):

$t_\mathrm{m} - t_\mathrm{a}$ [K]	400 [W/m^2]	700 [W/m^2]	1000 [W/m^2]
10	511	923	1335
30	421	834	1246
50	317	729	1141

Power output per collector unit [W] for collector HUJ 12/1.6 (aperture area of 1.003 m^2):

$t_\mathrm{m} - t_\mathrm{a}$ [K]	400 [W/m^2]	700 [W/m^2]	1000 [W/m^2]
10	290	525	759
30	421	474	708
50	317	415	649

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

$$P = P_{HUJ16/2.1} * \frac{A_a}{A_{a\,HUJ16/2.1}}$$

with:

P	= Collector output for a different collector of the series
$P_{HUJ16/2.1}$	= Collector output for collector HUJ 16/2.1 , (values see table)
A_a	= Aperture area of a different collector of the series
$A_{a\,HUJ16/2.1}$	= Aperture area of collector HUJ 16/2.1 = 1.764 m^2

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

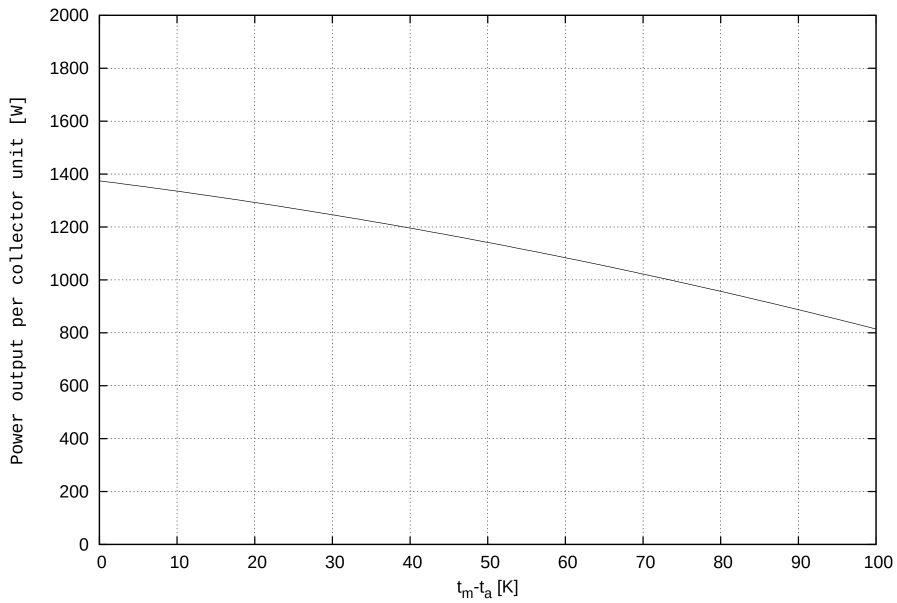

Figure 3: Power output for collector HUJ 16/2.1 based on 1000 W/m^2

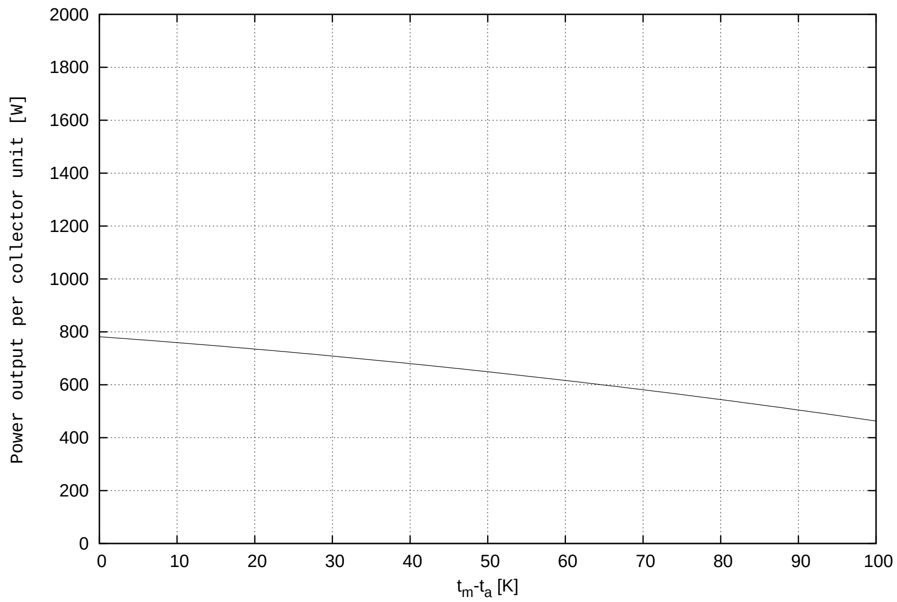

Figure 4: Power output for collector HUJ 12/1.6 based on 1000 W/m^2

7 Incidence angle modifier IAM

The incidence angle modifier IAM was measured at the outdoor test facility (tracker) of Fraunhofer ISE.

The measurement of the transversal IAM (transversal to the tubes) 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. 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 longitudinal IAM the orientation and the tilt angle of the tracker were tracked, which means a steady state measurement.

Test method:	outdoor - dynamic (transversal), steady state (longitudinal)
Latitude:	48.0°
Longitude:	7.8°
Collector tilt:	tracked
Collector azimuth:	transversal - fixed, longitudinal - tracked

IAM at θ:	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
transversal:	**1.00**	**1.02**	**1.04**	**1.12**	**1.25**	**1.45**	**1.63**	**1.60**	1.40	0.05
longitudinal:	**1.00**	1.00	1.00	1.00	0.99	**0.98**	0.94	0.83	0.58	0.00

Table 2: Measured **(bold)** and calculated IAM

8 Pressure drop

The measurement of the pressure drop Δp was carried out with water as fluid up to a flow rate of 450 kg/h. The inlet temperature of the water was 20°C. 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. In the following figure it can be seen that the flow is laminar until a flow rate of about 150 kg/h m^2 (almoust linear measurement points). A turbulent flow has a caracteristic which is quadratic, what can be seen in the complete curve.

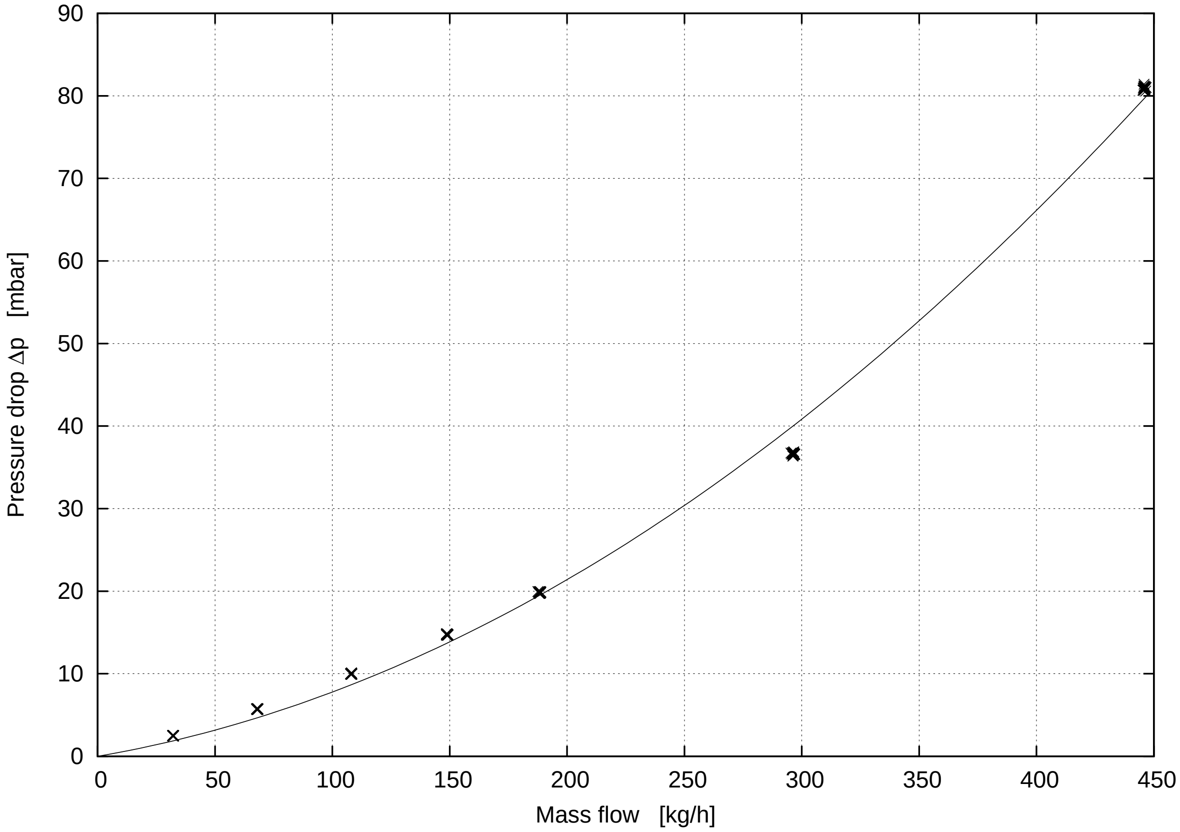

Figure 5: Measured pressure drop of the collector HUJ 16/2.1

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

$$\Delta p = 0.0486 * \text{x} + 0.00029 * \text{x}^2$$

Example values from fitted curve:

Mass flow [kg/h]	Pressure drop Δp [mbar]
0	0.0
100	7.8
200	21.4
300	40.8
400	66.1
500	97.2
600	134.2
700	177.0
800	225.6
900	280.1

Table 3: Example values for Δp

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 (HUJ 16/2.1):

34,63 kJ/K

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

19,63 kJ/K m^2

10 Internal pressure test

Maximum pressure specified by the manufacturer:	1300 kPa
Test temperature:	19.0 °C
Test pressure:	1950 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:	1027 W/m^2
Average surrounding air temperature:	20.7 °C
Average surrounding air speed:	< 0.5 m/s
Average absorber temperature:	242 °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 B 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 39 . The periods when the global irradiance G was higher than 850 W/m^2 and the surrounding air temperature t_a was higher than 10 °C was 115.8 h.

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

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

13 Internal thermal shock tests

Test conditions	1st test	2nd test
Outdoors:	yes	yes
Combined with exposure test:	yes	yes
Collector tilt angle:	45°	45°
Average irradiance:	892 W/m^2	903 W/m^2
Average surrounding air temperature:	22.1 °C	19.2 °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:	21.8 °C	22.3 °C
Duration of heat transfer fluid flow:	5 min	5 min
Absorber temperature immediately prior to heat transfer fluid flow:	244.0 °C	225.0°C
Result:	succeeded	succeeded

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

14 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:	941 W/m^2	830 W/m^2
Average surrounding air temperature:	23.2 °C	27.8 °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:	17.9 °C	16.5 °C
Duration of water spray:	15 min	15 min
Absorber temperature immediately prior to water spray:	226.0 °C	234.8 °C

15 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.

16 Freeze resistance test

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

17 Mechanical load test

17.1 Positive pressure test of the collector cover

The positive pressure (according to a positive pressure load caused by snow or wind) was not performed because it is not reasonable at this collector construction.

17.2 Negative pressure test of fixings of the header casing and the collector frame

The negative pressure (according to a negative pressure load caused by wind) was increased in steps of 100 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 header casing or at the fixings of the header casing and the collector frame was observed.

17.3 Negative pressure test of mountings

The manufacturer does not supply mountings for the collector HUJ 16/2.1 . The expeller will supply the mountings which have to be tested.

18 Internal pressure test (retest)

Maximum pressure specified by the manufacturer:	1300 kPa
Test temperature:	18.1 °C
Test pressure:	1950 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.

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:

$$t_{\text{s}} = t_{\text{as}} + \frac{G_{\text{s}}}{G_{\text{m}}} * (t_{\text{sm}} - t_{\text{am}}) \quad (2)$$

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

Measurement	Irradiance	Surrounding air temperature	Absorber temperature
	[W/m^2]	[°C]	[°C]
1	1040	20.2	243.1
2	1040	20.4	243.1
3	1041	20.2	243.1
4	1039	20.7	243.2
5	990	21.6	237.7
6	989	22.3	238.2
7	987	23.9	238.4
8	986	24.3	238.3
9	982	24.9	238.2
10	972	26	237.2
11	967	26.6	237.2
12	962	27.1	237
13	982	26.2	237.3
14	984	27.6	237.5
15	972	28.4	235.9

The resulting stagnation temperature is:

246 °C

20 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/ de-lamination/ wraping/ outgassing	0
Absorber coating	Cracking/ crazing/ blistering	0
Absorber tubes and headers	Deformation/ corrosion/ leak-age/ 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 documentation according EN 12975-1 chapter 7 was complete:

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

22 Summary statement

The measurements were carried out from July 2005 to March 2006.

No problems or distinctive observations occured during the measurements.

23 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 No. 2006-27

Freiburg, 29th November 2006
Fraunhofer-Institute for Solar Energy Systems ISE

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

A Efficiency curve

A.1 Efficiency curve with measurement points based on aperture area 1.764 m^2

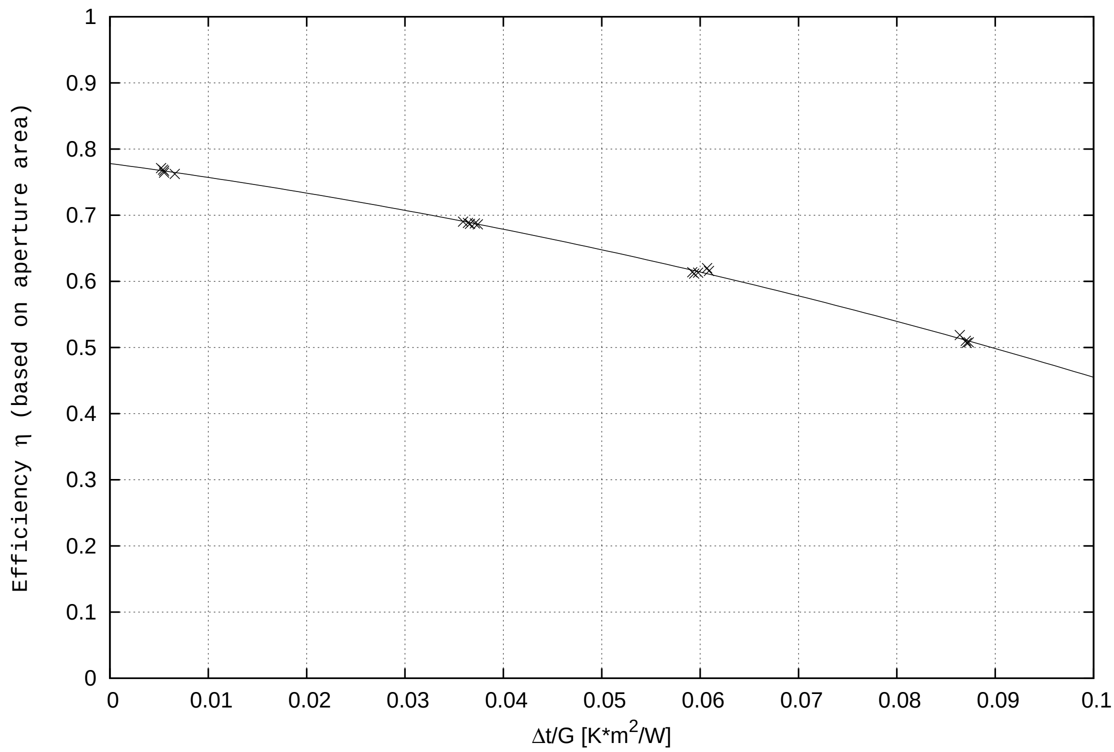

Figure 6: Efficiency curve with measurement points based on aperture area 1.764 m^2

Results:

The calculated parameters are based on following areas:

aperture area of 1.764 m^2:	absorber area of 1.522 m^2:
η_{0a} = 0.779	η_{0A} = 0.903
a_{1a} = 2.103 W/m^{2}K	a_{1A} = 2.437 W/m^{2}K
a_{2a} = 0.0107 W/m^{2}K^2	a_{2A} = 0.0124 W/m^{2}K^2

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

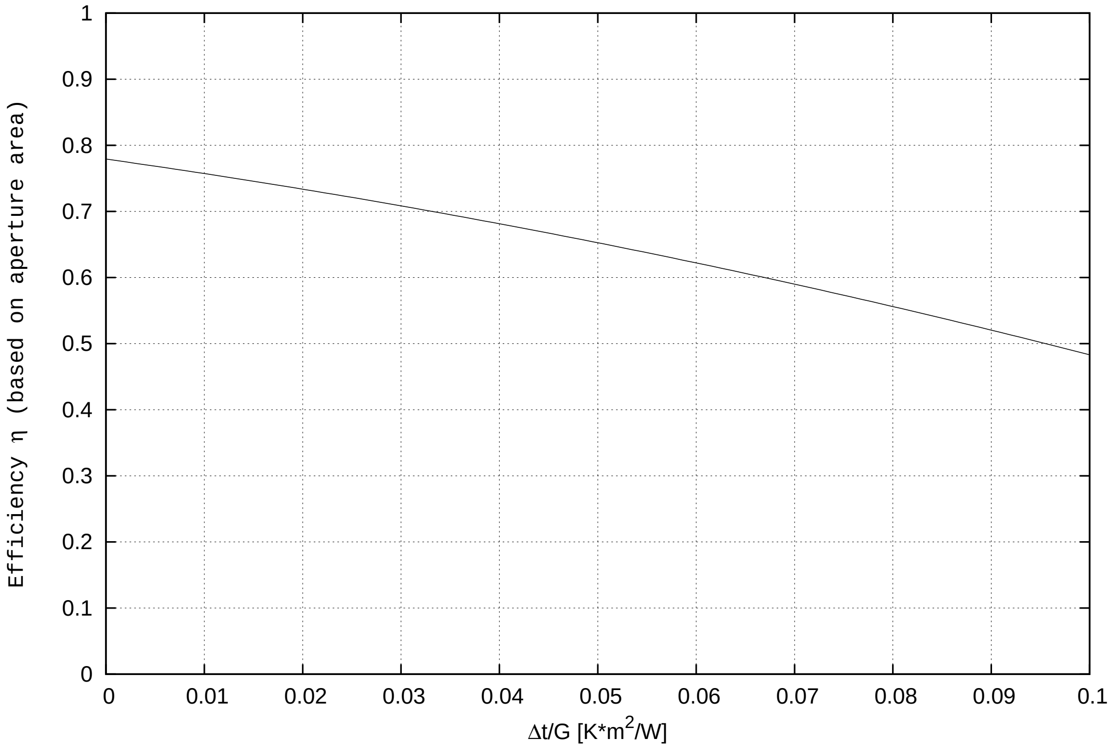

Figure 7: Efficiency curve scaled to 800 W/m^2 based on aperture area 1.764 m^2

The calculated parameters are based on following areas:

aperture area:	absorber area:
$\eta_{0.05a}$ = 0.652	$\eta_{0.05A}$ = 0.756

$\eta_{0.05}$ is the efficiency of the collector for the 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.

A.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 [-]
1039	0.12	134.5	6.20	15.10	8.90	10.65	3.84	6.81	0.0066	0.762
1023	0.12	134.4	6.23	15.02	8.79	10.62	4.98	5.64	0.0055	0.764
1011	0.12	134.3	6.23	14.98	8.75	10.61	5.18	5.42	0.0054	0.769
1004	0.12	134.3	6.22	14.89	8.67	10.55	5.08	5.48	0.0055	0.767
993	0.13	134.4	6.23	14.85	8.61	10.54	5.40	5.14	0.0052	0.771
1031	0.11	135.8	34.16	42.07	7.92	38.11	-0.40	38.52	0.0374	0.686
1031	0.12	135.8	34.16	42.09	7.94	38.12	-0.19	38.31	0.0371	0.687
1037	0.12	135.7	34.17	42.15	7.97	38.16	0.20	37.96	0.0366	0.687
1039	0.12	135.7	34.21	42.22	8.01	38.21	0.42	37.79	0.0364	0.688
1044	0.12	135.7	34.25	42.32	8.07	38.28	0.80	37.48	0.0359	0.690
981	0.16	133.6	62.32	69.16	6.83	65.74	7.07	58.67	0.0598	0.613
983	0.17	133.5	62.35	69.18	6.84	65.76	7.32	58.45	0.0594	0.612
972	0.17	133.5	62.36	69.14	6.78	65.75	8.14	57.61	0.0592	0.614
955	0.18	133.6	62.34	69.07	6.73	65.71	7.70	58.01	0.0607	0.620
947	0.18	133.5	62.36	68.98	6.62	65.67	8.01	57.66	0.0609	0.616
1060	0.13	140.2	90.15	95.94	5.79	93.04	0.74	92.31	0.0871	0.507
1057	0.13	140.2	90.12	95.91	5.78	93.02	0.77	92.25	0.0873	0.508
1058	0.13	140.4	90.18	95.99	5.81	93.09	1.03	92.05	0.0870	0.510
1056	0.12	141.2	90.35	96.21	5.86	93.28	2.07	91.22	0.0864	0.519

Table 4: Data of measured efficiency points

B Detais 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]
20050810	26.2	4.2	18.0	0.0
20050811	27.2	4.6	17.6	0.0
20050812	23.0	3.5	19.4	0.0
20050813	24.0	2.8	19.1	0.0
20050814	6.6	0.3	15.9	0.0
20050815	3.1	0.0	13.4	0.0
20050816	15.5	1.3	17.2	0.0
20050817	26.0	3.7	20.4	0.0
20050818	25.6	3.3	22.7	0.0
20050819	17.2	2.4	22.2	0.0
20050820	5.5	0.0	16.6	0.0
20050821	1.8	0.0	15.0	7.8
20050822	5.2	0.1	17.7	0.0
20050823	14.1	0.9	18.8	0.0
20050824	20.9	2.7	19.7	0.0
20050825	5.5	0.0	18.2	0.0
20050826	17.5	1.6	17.9	0.0
20050827	18.9	1.5	16.2	0.0
20050828	24.9	3.1	18.1	0.0
20050829	25.9	3.7	20.0	0.0
20050830	25.2	3.3	22.7	0.0
20050831	25.5	3.5	24.2	0.0
20050901	22.4	2.4	23.4	0.0
20050902	22.6	2.5	22.5	0.0
20050903	22.9	2.2	22.5	0.0
20050904	23.7	3.2	21.6	0.0
20050905	23.6	3.5	21.9	0.0
20050906	24.2	3.3	22.5	0.0
20050907	25.0	3.5	21.9	0.0
20050908	23.7	2.8	23.1	0.0
20050909	11.5	0.5	20.6	0.0
20050910	16.2	1.8	21.1	0.0
20050911	5.4	0.0	17.2	4.2

Continuation, see next page:

Date	H [MJ/m^2]	*valid period* [h]	t_a [°C]	*rain* [mm]
20050912	11.5	0.4	18.1	0.0
20050913	3.3	0.0	16.7	0.0
20050914	6.5	0.1	18.3	0.0
20050915	6.0	0.0	18.9	0.0
20050916	3.5	0.0	17.2	0.0
20050917	11.1	0.9	10.9	19.0
20050918	10.9	0.2	10.3	0.0
20050919	19.8	3.1	11.9	0.0
20050920	24.5	3.5	12.3	0.0
20050921	25.4	3.8	13.0	0.0
20050922	23.8	3.2	13.7	0.0
20050923	24.1	3.4	16.5	0.0
20050924	23.2	2.9	18.4	0.0
20050925	21.3	3.1	17.9	0.0
20050926	7.7	0.1	17.2	0.5
20050927	6.5	0.0	17.3	0.0
20050928	4.2	0.0	15.4	0.0
20050929	5.7	0.0	13.1	0.7
20050930	11.1	0.0	12.2	1.0
20051001	2.3	0.0	12.8	28.3
20051002	4.1	0.0	10.3	8.7
20051003	2.1	0.0	9.8	0.0
20051004	2.8	0.0	12.5	13.5
20051005	4.7	0.0	13.0	0.0
20051006	1.4	0.0	13.4	0.0
20051007	9.8	0.5	14.3	0.0
20051008	20.0	1.9	14.7	0.0
20051009	23.7	3.3	15.1	0.0
20051010	22.5	3.0	11.5	0.0
20051011	18.4	2.1	12.0	0.0
20051012	20.3	2.4	13.8	0.0
20051013	22.1	2.8	12.8	0.0
20051014	22.1	2.9	12.5	0.0