FORSCHUNGS- UND TESTZENTRUM
FÜR SOLARANLAGEN
STUTTGART

Institut für Thermodynamik und Wärmetechnik
Universität Stuttgart

Professor Dr.-Ing. habil. H. Müller-Steinhagen

Test Report
Thermal Performance of Solar Collector

acc. to EN 12975-2: 2001

Test Report No.: 02COL286

Stuttgart, Oct. 17th, 2002

Client:	**AMCOR Solar Energies Ltd.** **Ad-Halom Ind. Zone** **P.O.Box 3739** **Ashdod 77136** **Israel**
Manufacturer:	**AMCOR Solar Energies Ltd.**
Brand name:	**AM 2152 N**
Year of production:	**2002**

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Manufacturer:	AMCOR Solar Energies Ltd.	**Serial no.:**	44811055
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1 General Specifications (acc. to manufacturer)

Manufacturer

	AMCOR Solar Energies Ltd. Ad-Halom Ind. Zone P.O. Box 3739 Ashdod 77136 Israel
contact person:	Herr Amir Wolf Tel.: +972-8-8651444 Fax: +972-8-8651333
brand name:	AM 2152 N
serial no. :	44811055
serial product or prototype:	serial product
year of production:	2002

Dimensions of collector unit

determined by test laboratory

gross area:	2.82 m²
aperture area:	2.61 m²
absorber area:	2.58 m²

Technical Figures

collector type:	flat plate collector
length:	1893 mm (determined by test lab.)
width:	1487 mm (determined by test lab.)
height:	100 mm (determined by test lab.)
materials:	frame aluminium
weight:	48 kg
insulation material:	EPDM
collector mounting:	roof mounting

Absorber

material:	copper
thickness:	0.2 mm
surface treatment:	black chrome
absorptance:	0.96
emittance:	0.1
heat transfer fluid content:	5.36 liters
flow pattern:	13 tubes parallel
dimensions absorber tubes:	15.85 mm x 0.8 mm
number of absorber tubes:	13
distance between absorber tubes:	11.05 cm
dimensions of the header:	28.8 mm x 1 mm
no. of connections:	4
dimension of connections:	1” inside thread

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Transparent Cover

number:	1
material:	solar glass
manufacturer:	AFG Industries Inc., Kingsport, Tennessee, USA
brand name:	Solite Solar Glass
transmittance:	0.91
thickness:	3.2 mm

Thermal Insulation

material:	polyurethane foam
thermal conductivity:	0.022 W/(m K)
heat capacity:	not specified
density:	40-45 kg/m³
thickness:	25 mm

Limitations

stagnation temperature:	128 °C
max. admissible operation pressure:	12 bar
allowed heat transfer medium:	not specified
nominal flowrate per collector:	30 – 60 kg/h

Ascertainment of collector

construction characteristics:

AM 2152 N:
Solar Collector Assy. – A3-704481.000 – 12.03.02
Absorbing Plat Assy. – A3-704481.100 – 14.04.02
Upper/Lower Manifold – A3-704481.110 – 14.04.02
Pipe of Manifold – A3-704481.111 – 14.04.02
Crate – A3-704481.200 – 10.04.02
Casing – A3-704481.210 – 09.04.02

AM 2122 N:
Solar Collector Assy. – A3-704480.000 – 12.03.02
Absorbing Plat Assy. – A3-704480.100 – 12.03.02
Upper/Lower Manifold – A3-704480.110 – 09.04.02
Pipe of Manifold – A3-704480.111 – 02.04.02
Crate – A3-704480.200 – 09.04.02

AM 2082 N:
Solar Collector Assy. – 704487.000 – 10.09.02

technical data sheets:

Information about construction materials are included in construction characteristics.

Data sheet Polyurethane System – Caesarea Polymers Industries Ltd.

Data sheet Solite Solar Glass – AFG Glasses

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collector label:

The collector carries a visible and durable label. Following data is missing:

- year of production
- stagnation temperature at 1000 W/m² and 30°C
- volume of heat transfer fluid
- net weight of the collector

installer instruction manual:

The instruction manual is missing. It should contain the following data:

- dimensions and weight of the collector, instructions about the transport and handling of the collector;
- description of the mounting procedure;
- recommendations about lightning protection;
- instructions about the coupling of the collectors to one another and the connection of the collector field to the heat transfer circuit, including dimensions of pipe connections for collector arrays up to 20 m²
- recommendations about the heat transfer media which may be used (also in respect to corrosion) and precautions to be taken during filling, operation and service
- the maximum operation pressure, the pressure drop and the maximum and the minimum tilt angle;
- maintenance requirements.

All relevant documentation concerning personal safety, maintenance and handling of the product shall be made available to the customer in the national language of which country is sold.

Validity

The test report is valid for the above mentioned collector type AM 2152 N and the types AM 2122 N as well as AM 2108 N. Both are declared by the technical drawings mentioned in section “Ascertainment of collector”.

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2 Test Results of Thermal Performance

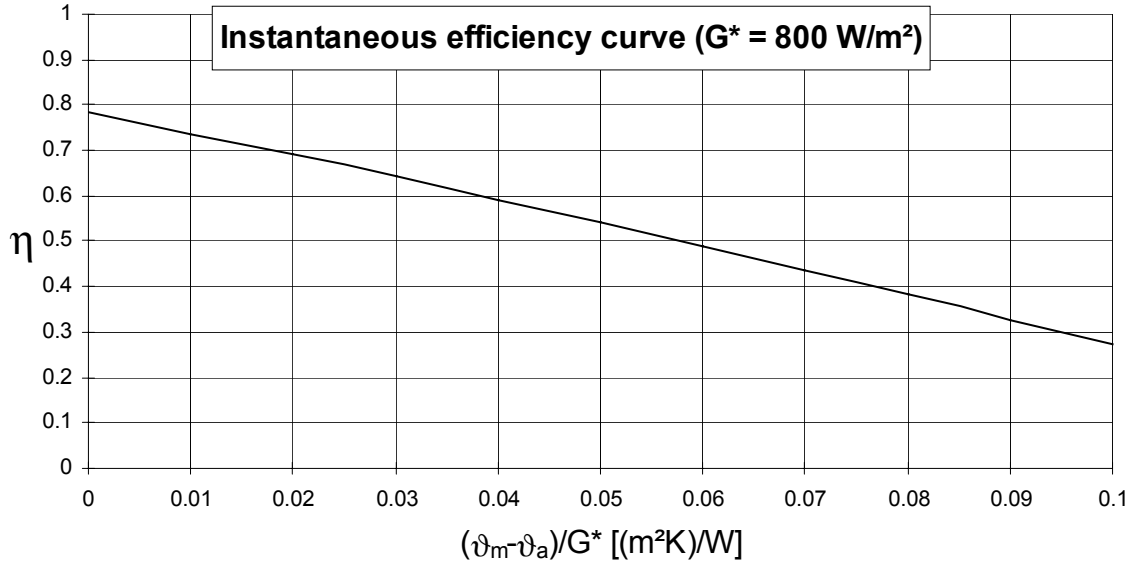
Determination of efficiency:

$$\eta = \eta_0 - a_1 \cdot \frac{(\vartheta_m - \vartheta_a)}{G*} - a_2 \cdot \frac{(\vartheta_m - \vartheta_a)^2}{G*}$$

(based on aperture area)

η_0	0.783
a_1 [W / (m²K)]	4.585
a_2 [W / (m²K²)]	0.007
incidence angle modifier $K_{\theta}(\theta)$ [-]	-
effective heat capacity C [J/K]	32496
volume flowrate [l/(m²h)]	60
used heat carrier	water

Table of efficiency (G* = 800 W/m²)



$(\vartheta_m-\vartheta_a)/G*$ [(m²K)/W]	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
η	0.783	0.737	0.690	0.641	0.592	0.541	0.489	0.437	0.383	0.328	0.272

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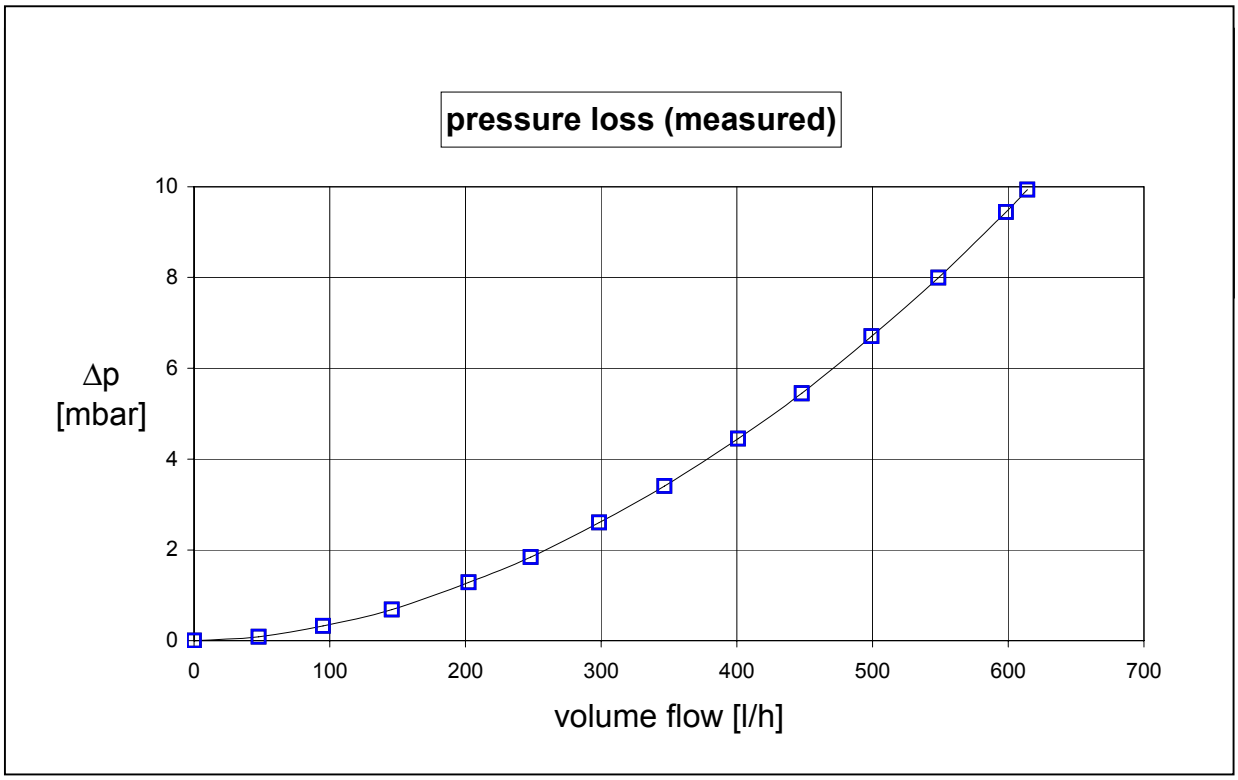
3 Pressure Loss Test Results

(water temperature ϑ = 20°C ± 2°C)



volume flow [l/h]	0.0	47.6	95.1	145.8	202.5	248.2	298.6
pressure loss [mbar]	0.0	0.1	0.3	0.7	1.3	1.8	2.6

volume flow [l/h]	346.8	400.8	447.9	499.4	548.7	598.4	614.2
pressure loss [mbar]	3.4	4.5	5.4	6.7	8.0	9.4	9.9

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4 Drawing *

* acc. to manufacturer

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5 Test Occurences and Operating Behaviour

Nothing particular.

6 Test Methods

The indoor test of the collector was carried out under stationary conditions according to EN 12975-2:2001 "Thermal solar systems and components – Solar Collectors – Part 2: Test methods". Water was used as heat carrier.

receipt of test sample:	Sept. 10th 2002
test period:	Sept. 16th to Oct. 2nd 2002
test engineer:	Dipl.-Ing. S. Fischer / Dipl.-Ing. E. Streicher

Stuttgart, Oct. 17th 2002

Prof. Dr.-Ing. H. Müller-Steinhagen

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Annex A: Prediction of the yearly energy gain

The prediction is based on the calculation of the yearly energy gains of the collector in a reference solar hot water system. This system is designed for a four-person-household. The calculation is done for aperture areas of 3, 4, 5 and 6 m² as well as for reference climate data of Hannover, Würzburg und Stötten (Ostalb).

collector characteristics (based on aperture area)		
conversion factor	heat transfer coefficient	area related heat capacity
η_0 = **0.783**	a_1 = **4.585 W/(m²K)**	
	a_2 = **0.007 W/(m²K²)**	c = **12.440 kJ/(m²K)**
incidence angle modifier	reference value: $K_{\theta b}(50°)$ = **0.89**	
	$K_{\theta d}$ = **0.82**	

system data of the ITW reference solar hot water system	
roof orientation:	south; tilt angle equal to latitude
collector piping:	15 m each to store, from store; nominal value DN 16; insulation thickness 25 mm, λ = 0,04 W/(mK), one half of each pipe is located outside, the other half is located inside
storage:	volume 300 l heat loss rate 2,2 W/K; ambient temperature 15°C volume auxiliary 135 l; set temperature 60 °C stratification number 100; effective vertical heat conductivity 2 λ_{Water}
heat:	immersed heat exchanger, $(kA)_{WT}$ = 9 W/(m²K); aperture area · $\vartheta_m^{0,6}$; (ϑ_m= average value of heat exchanger inlet temperature and local storage temperature in °C)
warm water consumption:	200 l/day ($7^{\underline{00}}$: 80 l; $12^{\underline{00}}$: 40 l; $19^{\underline{00}}$: 80 l); cold water temperature 10 °C; hot water temperature 45 °C; annual consumption: 2936 kWh/a

calculation results			
location	Hannover	**Würzburg**	Stötten
radiation [kWh/(m²a)]	1022	**1212**	1354
aperture area [m²]	yearly energy gain[1)] [kWh/(m²a)]		
3	426	515	561
4	386	470	510
5	354	**426**	463
6	325	388	421

[1)] energy gain of the collector without heat losses in the tubes and hot water store

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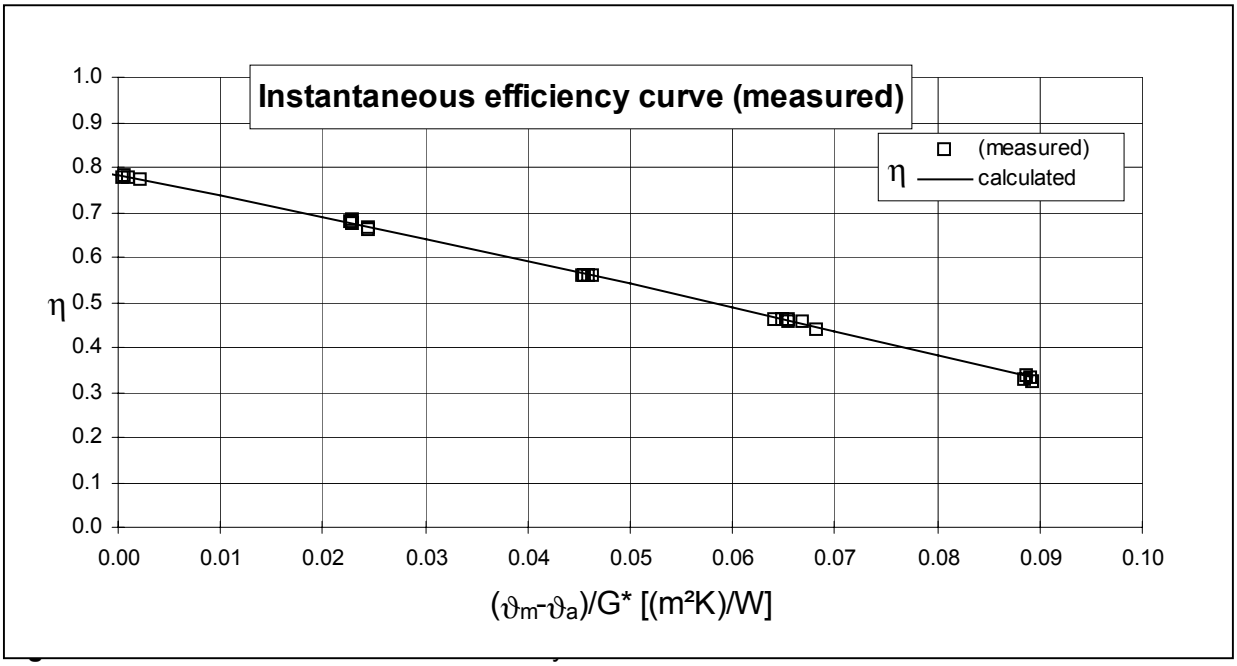
Annex B: Measured data

	G^*	G_d/G^*	$\dot{m}$	ϑ_{in}	ϑ_e	$\vartheta_e - \vartheta_{in}$	ϑ_m	ϑ_a	$\vartheta_m - \vartheta_a$	$(\vartheta_m - \vartheta_a)/G^*$	η
Nr	**[W/m²]**	**[ ]**	**[kg/h]**	**[°C]**	**[°C]**	**[K]**	**[°C]**	**[°C]**	**[K]**	**[(m²K)/W]**	**[ ]**
1	830.87	0.00	159.59	20.23	29.33	9.10	24.78	24.41	0.37	0.0004	0.7767
2	831.00	0.00	159.36	20.23	29.43	9.20	24.83	24.40	0.43	0.0005	0.7838
3	840.49	0.00	156.79	21.06	30.44	9.37	25.75	24.93	0.82	0.0010	0.7774
4	849.27	0.00	156.80	21.05	30.49	9.44	25.77	23.94	1.83	0.0022	0.7746
5	844.54	0.00	155.43	39.41	47.72	8.31	43.56	24.40	19.16	0.0227	0.6804
6	835.20	0.00	155.43	39.39	47.64	8.25	43.52	24.40	19.12	0.0229	0.6829
7	834.29	0.00	153.66	39.40	47.66	8.26	43.53	24.40	19.13	0.0229	0.6769
8	881.25	0.00	151.72	39.63	48.32	8.68	43.97	22.39	21.59	0.0245	0.6651
9	882.23	0.00	151.48	39.61	48.30	8.69	43.96	22.38	21.57	0.0245	0.6635
10	884.78	0.00	158.02	59.33	66.36	7.04	62.84	22.65	40.19	0.0454	0.5606
11	884.35	0.00	157.48	59.31	66.38	7.07	62.84	22.64	40.21	0.0455	0.5616
12	867.26	0.00	156.85	59.32	66.25	6.93	62.78	23.01	39.77	0.0459	0.5589
13	861.96	0.00	158.17	58.94	65.78	6.84	62.36	22.43	39.93	0.0463	0.5597
14	888.02	0.00	156.20	78.23	84.12	5.89	81.18	24.37	56.80	0.0640	0.4640
15	863.95	0.00	158.82	78.24	83.85	5.61	81.05	25.02	56.03	0.0648	0.4619
16	866.24	0.00	155.96	78.21	83.92	5.71	81.06	24.44	56.62	0.0654	0.4603
17	862.48	0.00	159.02	78.25	83.79	5.54	81.02	24.54	56.48	0.0655	0.4576
18	854.41	0.00	158.53	78.23	83.72	5.49	80.97	23.99	56.98	0.0667	0.4564
19	847.31	0.00	152.89	78.43	83.88	5.45	81.15	23.36	57.80	0.0682	0.4407
20	870.59	0.00	151.81	98.05	102.23	4.18	100.14	23.14	77.00	0.0885	0.3290
21	849.78	0.00	159.41	97.90	101.90	4.00	99.90	24.61	75.28	0.0886	0.3386
22	847.43	0.00	159.53	97.88	101.81	3.93	99.85	24.33	75.52	0.0891	0.3339
23	862.90	0.00	151.22	98.04	102.14	4.10	100.09	23.07	77.02	0.0893	0.3242

Table B.1: Measured values



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Annex C: Symbols and Units

a	[(mbar h²)/l²]	coefficient for calculation of pressure loss
a_1	[W/(m²K)]	heat transfer coefficient
a_2	[W/(m²K²)]	temperature depending heat transfer coefficient
b	[(mbar h)/l]	coefficient for calculation of pressure loss
b_0	[-]	factor to determine the incident angle modifier of the beam irradiance
C	[J/K]	heat capacity
c	[kJ/(m² K)]	area based heat capacity of the collector
c_1	[W/(m²K)]	heat transfer coefficient
c_2	[W/(m²K²)]	temperature depending heat transfer coefficient
c_5	[kJ/(m²K)]	area based heat capacity of the collector
$F'(\tau\alpha)_{en}$	[-]	conversion factor of the direct incidence intensity
G*	[W/m²]	hemispherical solar irradiance
G_b	[W/m²]	direct solar irradiance
G_d	[W/m²]	diffusive solar irradiance
$K_\theta(\theta)$	[-]	incident angle modifier of the hemispherical solar irradiance
$K_{\theta b}(\theta)$	[-]	incident angle modifier of the direct solar irradiance
$K_{\theta d}$	[-]	incident angle modifier of the diffusive solar irradiance
$(kA)_{WT}$	[W/K]	heat transfer capacity of the solar heat exchanger
$\dot{q}$	[W/m²]	area based collector performance
$\dot{V}$	[l/h]	volume flow
Δp	[mbar]	pressure loss
η	[-]	collector efficiency
η_0	[-]	conversion factor
λ	[W/(mK)]	heat conductivity
ϑ	[°C]	temperature
ϑ_a	[°C]	ambient air temperature
ϑ_e	[°C]	collector outlet temperature
ϑ_{in}	[°C]	collector inlet temperature
ϑ_m	[°C]	mean fluid temperature
θ	[°]	incidence angle of the direct solar irradiance