Test Report

Test for factory made solar thermal domestic water heating systems

Report No.: SYS08_02E

Saarbrücken, 2008-10-02

TZSB
Testzentrum Saarbrücken

in the

izes gGmbH
Institut für ZukunftsEnergieSysteme

Customer:

Efthimios G. Spanos
SKYLAND-COSMOSOLAR
32, Tavrou Street
17778 – Tavros, Athens
Greece

Description of the examined system :

Manufacturer:

Efthimios G. Spanos
SKYLAND-COSMOSOLAR
32, Tavrou Street
17778 – Tavros, Athens

Type: CS 300

Reference code of TZSB: SYS08_02E

Testing method: Performance characterization and reliability tests of a solar domestic hot water system according to EN 12976-1,2:2006 and ISO 9459 – 5:2007

Index of contents

1 Description of the examined system

Solar thermal domestic water heating system consisting of two flat plate collectors and a pressurized horizontal storage tank as thermosiphon system. The auxillary heating of the system is realised with an electrical resistance with incorporated thermostat.

Name of the customer:	Efthimios G. Spanos, SKYLAND-COSMOSOLAR
Name of the manufacturer:	Efthimios G. Spanos, SKYLAND-COSMOSOLAR
Trade name:	CS 300

1.1 Collector

Manufacturer:	Efthimios G. Spanos, SKYLAND-COSMOSOLAR
Name:	EPI 510
Manufacturing number:	08030022 (Kollektor 1), 08030023 (Kollektor 2)
Type:	Flat plate collector
Drawing number:	n.a.
Manufacturing date:	n.a.
Mass flow rate:	n.a.
Max. operating pressure:	10 bar
Stagnation temperature at 1000 W/m^2 and 30 °C ambient temperature	184 °C
Fixation and mounting of the collector:	Flat plate collectors integrated in the mounting frame of the thermosiphon system

Measures of the collector

Gross area:	2.0 m² (manufacturer information)
Aperture area (reference area for performance prediction):	1.758 (1.918 m x 0.916 m) Kollektor 1 1.759 (1.918 m x 0.917 m) Kollektor 2
Absorber area:	n.a.
Height:	95 mm (manufacturer information)
Net weight:	37.76 kg (manufacturer information)
Fluid content:	1.43 l (manufacturer information)
Number of risers:	n.a.

Cover:

Number of covers:	1
Material:	Tempered security, low-iron glass
Manufacturer:	n.a.
Name of the product:	n.a.
Thickness:	4 mm (manufacturer information)
Dimensions of cover:	n.a.
Transmittance of the cover:	0.93 (manufacturer information)

Absorber

Material of the absorber:	Aluminium
Flowed element:	Copper tube
Length of the absorber:	n.a.
Width of the absorber:	n.a.
Thickness of the absorber:	n.a.
Solar absorption ratio, α:	0.95 (manufacturer information)
Hemispherical emission ratio, ε:	0.05 (manufacturer information)
Surface treatment:	Selective titanium coating (manufacturer information)

Heat transfer medium:

Used medium during the test (collector loop):	Mixture of water and propylene glycol

Limit values:

Stagnation temperature:	184 °C
Max. operating pressure:	10 bar
Max. flow rate:	n. a.

1.2 Piping (test bed, domestic water sided, not delivered by the manufactuer)

Material:	High quality steel (corrugated pipe)
Nominal diameter:	DN 16
Length of piping (inside/outside of the building):	Flow: 8 m / 6 m Reverse flow: 6 m / 8 m
Insulation:	Material: high temperature insulation Thickness: 16 mm
Safety valve:	½ ", 6 bar
Expansion vessel:	18 liter, primary pressure 4 bar
Lock valve:	In reverse flow
Indication of the flow rate:	Flow indicator, indication range 6 - 15 l/min
Manometer:	0 -16 bar

1.3 Storage tank

Manufacturer:	Cosmosolar
Type:	Stainless Steel, 2 mm
Manufacturing number:	n. a.
Construction type:	Pressurized horizontal storage tank as thermosiphon system
Nominal capacitiy:	300 liter (manufacturer information)
Net content:	269 liter (determined by TZSB)
Length:	2050 mm
Diameter:	580 mm
Insulation:	Expanded P.U.
Corrosion protection:	Magnesium anode
Operating temperature:	n.a.
Maximum pressure:	10 bar
Built in heating element:	1.5 kW (nominal) Art.-Nr. TU S00283 29-07

Photo of the thermosiphon system on the test bed

Figure 1

Sketches of the thermosiphon system

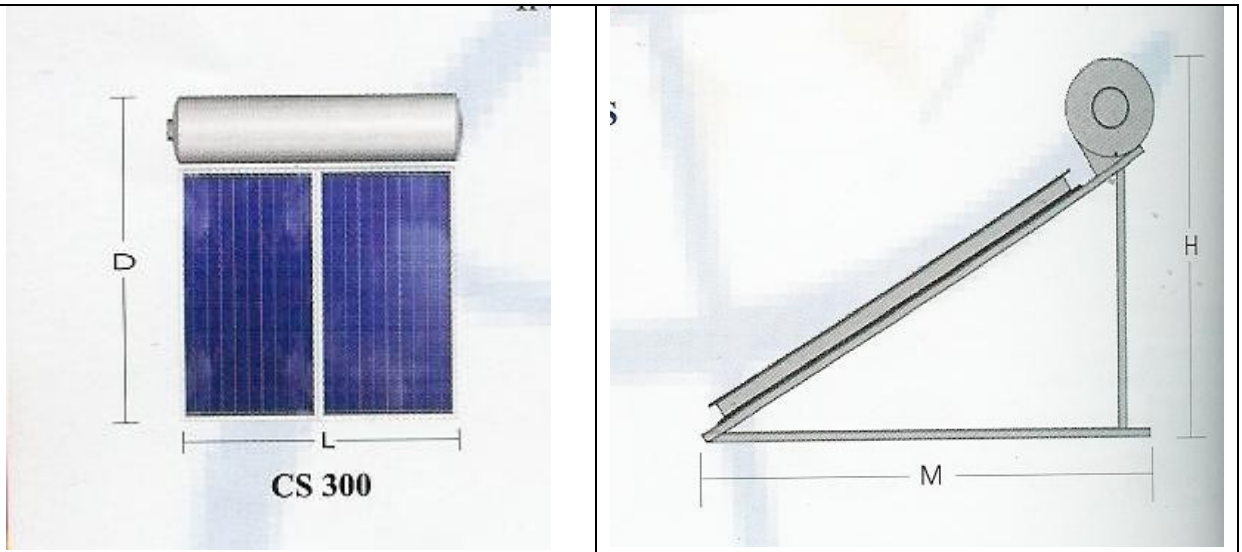

Figure 2

2 Test of the thermal performance for factory made solar thermal heating systems according to EN 12976-2: 2006

2.1 Test method

Dynamic system test according to EN 12976 - 2: 2006 (Thermal solar heating systems and their components - factory made systems - Part 2: Test methods). The testing method corresponds to the demands of ISO 9459 - 5: 2007 (Solar heating - Domestic water heating systems - Part 5: System performance characterization by means of whole-system tests and computer simulation).
The identification of the system parameters is carried out by InSitu Scientific Software DF2.7. the performance prediction is performed according to EN 12976 - 2: 2006.

2.2 Installation of the system

The installation of the system is carried out according to the demands of the manufacturer.. The solar thermal domestic water heating system consists of two plat plate collectors and a pressurized horizontal storage tank as thermosiphon system. The storage tank of the thermosiphon system is mounted outdoor. The auxillary heating of the system is realised with a heating element with incorporated thermostat. The connections for cold water and hot water are thermally insulated according the heating system regulation.
Tilt angle of the flat plate collectors: 45.4°
Azimuth angel of the vacuum tubes: - 3.65°

2.3 Relevant system and regulation parameters during the performance test

Aperture area A_C :	3.517 m² (two collectors)
Storage tank volume (net content) VS :	269 liter
Factor V_S/A_C (according to ISO 9459-5):	76.49
Draw-off volume during test A:	67.25 liter each draw-off
Treshold temperature during test B:	60 °C
Adjusted collector loop flow rate:	Thermosiphon system
Activating temperature difference:	n. a.
Deactivating temperature difference:	n. a.
Auxillary heating power:	1.25 kW (effective electrical power, measured at TZSB)
Set temperature of auxillary heating:	52.5 °C

2.4 Description of the measured data

Sequence name	Measure period (incl. conditioning)
SOL08_04	2008-05-08 until 2008-05-13 3 valid B-days, with auxiliary heating
STO08_02	2008-05-12 until 2008-05-17 2 valid B-days without auxiliary heating, 2 days without draw-off and solar irradiation
SOL08_05	2008-05-19 until 2008-05-23 3 valid A-days, without auxiliary heating
SOL08_06	2008-05-26 until 2008-05-31 3 valid A-days, without auxiliary heating
AUX08_03	2007-11-03 until 2007-11-08 4 valid B-days without solar irradiation, with auxiliary heating

2.5 System parameters

Parameters, standard deviation and correlation matrix

	A_C* [m²]	u_C* [W/(m²K)]	U_S [W/K]	C_S [MJ/K]	f_{aux} [-]	D_L [-]	S_C [-]	Obj. [W]
Parameter	2.071	5.331	2.335	1.082	0.9483	0.1204	0.003965	16.466
Standard deviation	± 0.0332	± 0.199	± 0.0854	± 0.0127	± 0.0802	± 0.0191	± 0.0141	
Correlation matrix								
	1.0000000	0.537583	-0.102886	-0.366716	0.003433	0.101817	-0.766348	
	0.537583	1.0000000	-0.285635	-0.285635	-0.250821	-0.359818	-0.255468	
	-0.102886	-0.285635	1.0000000	0.341774	0.378579	-0.391320	0.041773	
	-0.366716	-0.285635	0.341774	1.0000000	-0.047438	-0.459512	0.448915	
	0.003433	-0.250821	0.378579	-0.047438	1.0000000	-0.081166	-0.007205	
	0.101817	-0.359818	-0.391320	-0.459512	-0.081166	1.0000000	-0.118061	
	-0.766348	-0.255468	0.041773	0.448915	-0.007205	-0.118061	1.0000000	

Description of the system parameters:

A_C*	[m²]	Effective collector area
u_C*	[W/(m²K)]	Effective collector loss coefficient for collector loop
U_S	[W/K]	Total store heat loss coefficient
C_S	[MJ/K]	Total store heat capacity
F_{aux}	[-]	Fraction of the storage volume used for auxiliary heating
D_L	[-]	Mixing constant, describing mixing effects during cold water inlet
S_C	[-]	Stratification parameter, $S_C = 0$ is equivalent to a heat exchanger immersed at the bottom
Obj.	[W]	Parameter to characterize the quality of the parameter identification

The parameters were acquired with the following options:

"Model,Aux,On", "Model,LoadHeatExchanger,Off", "Model,DrawOffMix,On", "Model,WindCollector,Off" and "Model,SolarStratification,On"

2.6 Performance prediction according to EN 12976-2: 2006

2.6.1 Performance prediction for location Würzburg

Reference conditions for performance prediction:

Collector orientation:	South; tilt angle 45°
Collector area:	Aperture area: 3.517 m² (two collectors)
Clima conditions:	Reference climate data for Würzburg
	(geogr. latitude 49.8 °N, geogr. longitude 9.9 °O, UTC+1)
Store:	Store ambient temperature corresponding to ambient temperature
Hot water consumption:	50 - 600 l/d at one draw-off ($19^{\underline{00}}$: 100 %)
	Draw-off flow rate 10 l/min; cold water temperature 10 ± 3 °C
	Hot water temperature after mixing 45 °C
Auxiliary heating:	Auxiliary power 1250 W, set temperature 52.5 °C, 24 h

Performance of the solar-plus-supplementary system for climate conditions of Würzburg

Irradiance: 4415 MJ/(m²a) on 45° plane

Draw-off volume [l/d]	50	80	110	140	170	**200**[*5]	250	300	400	600
Q_d Heat demand[*1] [MJ/a]	2677	4289	5897	7506	9114	**10691**	13371	16052	21413	32167
Q_L Heat delivered [*2] [MJ/a]	2677	4289	5897	7506	9114	**10691**	13245	15358	18165	20561
$Q_{aux,net}$ Auxiliary energy demand [*3] [MJ/a]	2725	3910	5203	6528	7916	**9335**	11605	13497	16115	18322
Q_{par} Parasitic energy[*4] [MJ/a]	0	0	0	0	0	**0**	0	0	0	0

[*1] **Q_d**: Heat demand which is provided to the user corresponding to the draw-off volume

[*2] **Q_L**: Heat delivered by the solar heating system according to ISO 9459-5:2007

[*3] **$Q_{aux,net}$**: Auxiliary energy demand according to ISO 9459-5: 2007

[*4] **Q_{par}**: The parasitic energy

[*5] Designed load for the system, given by the manufacturer. The energy delivered to the user is at least 90 % of the yearly heat demand

2.6.2 Performance prediction for location Athens

Reference conditions for performance prediction:

Collector orientation:	South; tilt angle 45°
Collector area:	Aperture area: 3.517 m² (two collectors)
Clima conditions:	Reference climate data for Athens
	(geogr. latitude 38.0 °N, geogr. longitude 23.7 °O, UTC+2)
Store:	Store ambient temperature corresponding to ambient temperature
Hot water consumption:	50 - 600 l/d at one draw-off ($19^{\underline{00}}$: 100 %)
	Draw-off flow rate 10 l/min; cold water temperature 17.8 ± 7.4 °C
	Hot water temperature after mixing 45 °C
Auxiliary heating:	Auxiliary power 1250 W, set temperature 52.5 °C, 24 h

Performance of the solar-plus-supplementary system for climate conditions of Athens

Irradiance: 4888 MJ/(m²a) on 45° plane

Draw-off volume [l/d]	50	80	110	140	170	**200**[*5]	250	300	400	600
Q_d Heat demand[*1] [MJ/a]	2081	3343	4573	5834	7064	**8326**	10407	12488	16651	24977
Q_L Heat delivered [*2] [MJ/a]	2081	3343	4573	5834	7064	**8326**	10407	12425	15642	18449
$Q_{aux,net}$ Auxiliary energy demand [*3] [MJ/a]	1198	1892	2731	3595	4541	**5550**	7348	9145	12141	14790
Q_{par} Parasitic energy[*4] [MJ/a]	0	0	0	0	0	**0**	0	0	0	0

[*1] **Q_d**: Heat demand which is provided to the user corresponding to the draw-off volume

[*2] **Q_L**: Heat delivered by the solar heating system according to ISO 9459-5:2007

[*3] **$Q_{aux,net}$**: Auxiliary energy demand according to ISO 9459-5: 2007

[*4] **Q_{par}**: The parasitic energy

[*5] Designed load for the system, given by the manufacturer. The energy delivered to the user is at least 90 % of the yearly heat demand

2.6.3 Performance prediction for location Stockholm

Reference conditions for performance prediction:

Collector orientation:	South; tilt angle 45°
Collector area:	Aperture area: 3.517 m² (two collectors)
Clima conditions:	Reference climate data for Stockholm
	(geogr. latitude 59.35 °N, geogr. longitude 18.07 °O, UTC+1)
Store:	Store ambient temperature corresponding to ambient temperature
Hot water consumption:	50 - 600 l/d at one draw-off ($19^{\underline{00}}$: 100 %)
	Draw-off flow rate 10 l/min; cold water temperature 8.5 ± 6.4 °C
	Hot water temperature after mixing 45 °C
Auxiliary heating:	Auxiliary power 1250 W, set temperature 52.5 °C, 24 h

Performance of the solar-plus-supplementary system for climate conditions of Stockholm

Irradiance: 4005 MJ/(m²a) on 45° plane

Draw-off volume [l/d]	50	80	110	140	170	**200**[*5]	250	300	400	600
Q_d Heat demand[*1] [MJ/a]	2791	4478	6150	7821	9492	**11164**	13970	16746	22327	33428
Q_L Heat delivered [*2] [MJ/a]	2791	4478	6150	7821	9492	**11164**	13844	16020	18669	20593
$Q_{aux,net}$ Auxiliary energy demand [*3] [MJ/a]	3056	4384	5834	7285	8799	**10312**	12772	14790	17250	18985
Q_{par} Parasitic energy[*4] [MJ/a]	0	0	0	0	0	**0**	0	0	0	0

[*1] **Q_d**: Heat demand which is provided to the user corresponding to the draw-off volume

[*2] **Q_L**: Heat delivered by the solar heating system according to ISO 9459-5:2007

[*3] **$Q_{aux,net}$**: Auxiliary energy demand according to ISO 9459-5: 2007

[*4] **Q_{par}**: The parasitic energy

[*5] Designed load for the system, given by the manufacturer. The energy delivered to the user is at least 90 % of the yearly heat demand

2.6.4 Performance prediction for location Davos

Reference conditions for performance prediction:

Collector orientation:	South; tilt angle 45°
Collector area:	Aperture area: 3.517 m² (two collectors)
Clima conditions:	Reference climate data for Davos
	(geogr. latitude 46.82 °N, geogr. longitude - 9.82 °O, UTC+1)
Store:	Store ambient temperature corresponding to ambient temperature
Hot water consumption:	50 - 600 l/d at one draw-off ($19^{\underline{00}}$: 100 %)
	Draw-off flow rate 10 l/min; cold water temperature 5.4 ± 0.8 °C
	Hot water temperature after mixing 45 °C
Auxiliary heating:	Auxiliary power 1250 W, set temperature 52.5 °C, 24 h

Performance of the solar-plus-supplementary system for climate conditions of Davos

Irradiance: 6055 MJ/(m²a) on 45° plane

Draw-off volume [l/d]	50	80	110	140	170	**200**[*5]	250	300	400	600
Q_d Heat demand[*1] [MJ/a]	3027	4857	6654	8483	10281	**12110**	15137	18165	24220	36266
Q_L Heat delivered [*2] [MJ/a]	3027	4857	6654	8483	10281	**12110**	15074	17692	21224	23715
$Q_{aux,net}$ Auxiliary energy demand [*3] [MJ/a]	1798	3106	4573	6055	7632	**9272**	11952	14349	17629	19899
Q_{par} Parasitic energy[*4] [MJ/a]	0	0	0	0	0	**0**	0	0	0	0

[*1] **Q_d**: Heat demand which is provided to the user corresponding to the draw-off volume

[*2] **Q_L**: Heat delivered by the solar heating system according to ISO 9459-5:2007

[*3] **$Q_{aux,net}$**: Auxiliary energy demand according to ISO 9459-5: 2007

[*4] **Q_{par}**: The parasitic energy

[*5] Designed load for the system, given by the manufacturer. The energy delivered to the user is at least 90 % of the yearly heat demand

2.7 Determination of the ability of solar-plus-supplementary systems to cover the load

2.7.1 Description of the test procedure

The determination of the ability of solar-plus-supplementary systems to cover the load according to EN 12976 – 2: 2006 is carried out in order to ensure that the solar-plus-supplementary system is able to cover the maximum daily load without solar contribution. For the determination of the ability to cover the maximum daily load by means of numerical simulation the model given in ISO 9459-5: 2007 is used. During the calculation process the solar irradiation is set to zero. The maximum power of the heating element was simulated with 1.25 kW and a set point temperature of the drinking water of 52.5 °C. The cold water inlet temperature is set to the cold water temperature (average - amplitude) at the respective location. The test with the duration of one daily load cycle is considered as valid, if during 95% of the draw-off time the hot water temperature does not drop below 45 °C. The daily load cycle consists of the following draw-offs with a flowrate of 10 l/min:

t= t_0 + 12 h: withdraw of 40% the daily load volume

t= t_0 + 17 h: withdraw of 20% the daily load volume

t= t_0 + 22 h: withdraw of 40% the daily load volume

At time t_0 the auxillary heating is set into operation and is activated during the daily load cycle.

2.7.2 Results of the test

Location	Lowest cold water temperature [°C]	Maximum ability to cover the daily load [l/d]	Draw-off time [min]	Time ≥ 45 °C [%]	System fails to cover the daily load [l/d]	Draw-off time [min]	Time ≥ 45 °C [%]
Würzburg	7	**370**	37	94.2	380	38	89.1
Stockholm	2.1	**340**	34	100	350	35	85.6
Davos	4.6	**340**	34	100	350	35	86.8
Athen	10.4	**390**	39	91.7	400	40	82.0

The declared design load (manufacturer information) of 200 l/d is exceeded.

3 Testing of the safety and reliability of factory made thermal solar systems according EN 12976-2: 2006

3.1 Over temperature protection

Procedure of the over temperature protection according to EN 12976-2: 2006, chapter 5.2.The test of the system was carried out outdoor.
The auxillary heating was activated. Set point temperature for the auxillary heating: 52.5 °C
Start testing: 2008-06-20, at 0:00 o'clock (MESZ)

Details testing procedure:

	Date	*Sum of solar irradiation*	*T_{amb}(13:28 o'clock)*	*conditions fullfilled*
Day 1:	2008-06-21	21.51 MJ/m²	24.98 °C	yes
Day 2:	2008-06-22	17.41 MJ/m²	28.19 °C	no
Day 3:	2008-06-23	20.04 MJ/m²	24.02 °C	yes
Day 4:	2008-06-24	21.60 MJ/m²	28.13 °C	yes

On 2008-06-25, at 15:27 o'clock start of a conditioning. Withdraw of 437 l with a flowrate of 10 l/min

Result of testing: No major failure according to EN 12976-2: 2006, chapter 5.2

3.2 Pressure resistance

Test of pressure resistance of all hydraulic components according to EN 12976-2 : 2006, chapter 5.3

Test conditions:

	Solar - loop	**Storage tank**
max. working pressure	10 bar	10 bar
Test pressure	13 bar	15 bar
Duration of testing	15 min	15 min
Result	No failure	No failure

Result of testing: No major failure according to EN 12976-2: 2006, chapter 5.3

3.3 Safety equipment

Check of the safety equipment according to EN 12976-2 : 2006, chapter 5.6

Information to the used components:

Safety valves: Are in accordance to EN 12976-1: 2006, chapter 4.4.1

Safety lines and expansion lines: inexistent

Blow-off lines: inexistent

Result of testing: No major failure according to EN 12976-2: 2006, chapter 5.6

3.4 Summary of test results

Type of test	Result
2. Characterisation of the thermal performance	see chapter 2
3.1 Over temperature protection	No failure
3.2 Pressure resistance	No failure
3.3 Safety equipment	No failure

4 Occurrences during the test and additional notes

None

5 Test method

Test according to EN 12976-1:2006 "Thermal solar systems and components – Factory made systems – Part 1: general requirements".
Determination of the thermal performance according to ISO 9459-5:2007 "Solar Heating - Domestic water heating systems - Part 5: System performance characterization by means of whole-system tests and computer simulation".

Delivery of the test item:	2008-04-22
Start of the test:	2008-04-30
End of the test:	2008-09-15
Test engineers:	Dipl.-Ing. (FH) Thomas Bischoff, Dipl.-Ing. (FH) Danjana Theis

TZSB Saarbrücken, 2008-10-02

Dipl.-Ing. (FH) Danjana Theis	Dipl.-Ing. (FH) Thomas Bischoff
head of the test lab	*test engineer*

For customer information:

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DAP-PL-3450.00

DIN CERTCO
Approved Testing Laboratory

The TZSB holds the accreditation according to **DIN EN ISO/IEC 17025:2005** by **DAP GmbH**.
The scope of the accreditation contains the test for thermal solar systems and its components according to DIN 4757 - 2, DIN EN 12975-1,2, DIN EN 12976-1,2, DIN V ENV 12977-1,2,3,
ISO 9806 – 1, 2, 3, AS/NZS 2535.1 and AS/NZS 2712 Section 4 and 6. The accreditation is registered under number **DAP-PL-3450.00**. The TZSB is an approved testing laboratory of DIN CERTCO.

Our tests are valid in the member countries of European co-operation for Accreditation (EA) and the International Laboratory Accreditation Cooperation (ILAC)

Argentina – Australia – Austria – Belgium – Brazil – Canada – China – Costa Rica – Cuba – Czech Republic – Denmark – Egypt – Finland – France – Germany – Greece – Hongkong – India – Indonesia – Ireland – Israel – Italy – Japan – Republic of Korea – Malaysia – Mexico – Netherlands – New Zealand – Norway – Philippines – Poland – Romania – Singapore – Slovakia – Slovenia – South Africa – Spain – Sweden – Switzerland –Taiwan – Thailand – Turkey – United Kingdom – USA – Vietnam
(as at 2007-01-01, current informations on www.ilac.org and www.european-accreditation.org)