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ilac-MRA SWISS TESTING STS 301

Test Report S249EN

System model: **NATURAL SOL 280 V2**

Contract party:
IMMERGAS S.p.A.
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IT-42041 Brescello

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Sample received: 13.07.2016

Start of test: 20.07.2016

End of test: 21.11.2016

Test standard: EN 12976:2006

Note: Manufacturers' information is printed in *italics*.

Content:

Page

1 Description of the system

1.1 Manufacturer

Name:	IMMERGAS S.p.A.
Address:	Via Cisa Ligure 95
Postcode / City:	IT-42041 Brescello
Country:	Italy
Phone:	+39 522 689 450
Fax:	+39 522 689 178
E-mail:	sales-export@immergas.com

1.2 Test pattern

System model:	NATURAL SOL 280 V2
Serial number of tested unit:	7543

1.3 System classification

System type:	Thermosiphon
Heat transfer:	Indirect
Solar system:	Closed
Collector loop:	Filled
Location of heat storage:	Close-coupled system
Other (specify):	--

1.4 Heat transfer medium:

Specification:	*Water-propylene glycol mixture / concentration of glycol 30-50 % vol.*
Total medium content:	*18.8 l*

1.5 Antifreeze protection: cp. 1.4

1.6 Number of collector modules: 2

1.7 Collector

Manufacturer:	SAMMLER B. Michalopoulos sa
Type:	Flat plate collector
Model name:	ARIS2004
Certifications:	Solar Keymark, Register No. 011-7S494 F
Test report:	C1702LPEN
Serial number:	31139
Gross area:	*2.110 m^2*
Aperture area:	*1.907 m^2*
Number of covers:	1
Cover material(s)/ Manufacturer:	Toughened glass
Cover thickness:	3.2 mm
Insulation material(s):	Rockwool
Insulation thickness:	40 mm (back) *density 30 kg/m^3*
Casing material:	Aluminium
Fluid volume of collector area (without the connection piping between the collector(s) and the tank):	1.45 l
Weight of collector without fluid:	38.0 kg/collector
Gross dimensions (L x W x H):	2.037 m x 1.036 m x 0.090 m

1.8 Absorber

Manufacturer:	Prime Laser Technology
Material(s):	Aluminium sheet / copper tubes
Type of absorber:	Plane
Flow type:	Parallel
Number of tubes / channels:	9
Absorber tube dimensions:	Outer diameter 8 mm x wall thickness 0.5 mm
Distance between tubes:	100 mm
Absorber area:	1.89 m^2
Sheet thickness:	0.5 mm
Bonding technique:	Laser welding

Coating of Absorber

Manufacturer:	*Alanod*
Coating:	*Mirotherm selective coating, Titanium Oxide*

1.9 Storage tank

Manufacturer:	SAMMLER B. Michalopoulos sa
Serial number:	7543
Model name / Type:	SV300 / horizontal
Material:	Steel
Volume:	300 l
Outside diameter:	580 mm
Insulation material:	Polyurethane foam
Insulation thickness:	40 mm
Heat exchanger(s):	Mantle heat exchanger
Max. operating pressure:	10 bar
Protection against corrosion:	Enamelled, Mg sacrificial anode

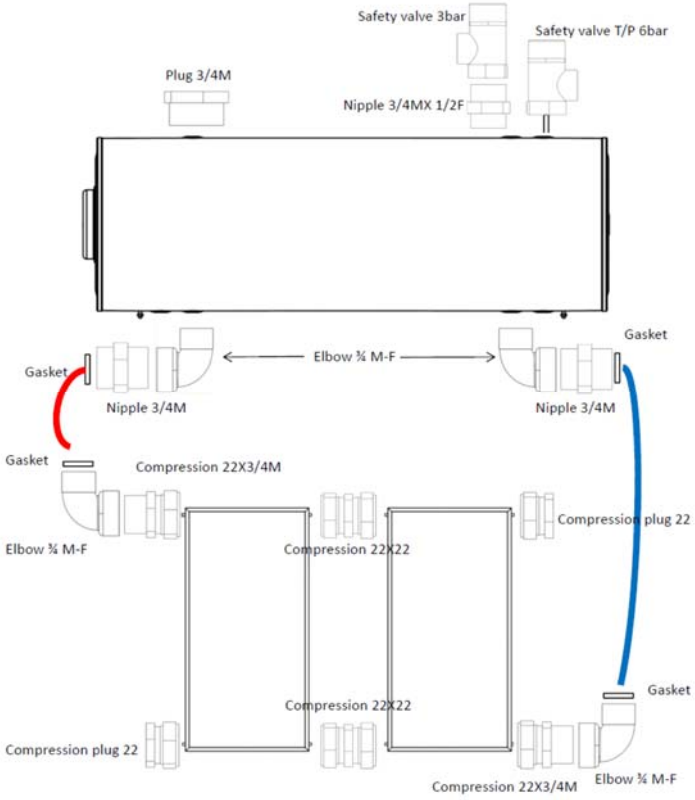
1.10 Pump

Manufacturer:	--
Model name / Type:	--
Electrical power:	--

1.11 Controller

Manufacturer:	--
Model name / Type:	--

1.12 Schematic of system



1.13 Picture of system

Fig. 1: Thermosiphonsystem NATURAL SOL 280 V2

1.14 Connecting piping between the collector(s) and the tank

Diameter:	DN16, corrugated pipe
Length:	*3.3 m*
Material:	Stainless steel
Insulation material:	Elastomeric insulation coated with a polymer membrane (UV protection)
Insulation thickness:	9 mm

1.15 System data

Recommended tilt angle of collector area[1]:	*45° to horizontal*
Collector mounting:	Tilted and flat roof installation with support construction
Module orientation during test:	Vertical
Collector loop flow rate:	n/a
Remarks:	--

1.16 Comments on system design

The drinking water circuit has a temperature and pressure relief valve (90°C, 6 bar). The collector loop is fitted with a pressure relief valve of 3 bar. The test was performed without an optional electrical resistance heater (4 kW).

1.17 Documentation

Documents for the installer: The system is accompanied by an installer manual according to the requirements of the EN 12976-1:2006 chapter 4.6. The following information is missing in the installation manual:

None

Documents for the user: The system is accompanied by an owner's manual according to the requirements of the EN 12976-1:2006 chapter 4.6. The following information is missing in the owner's manual:

None

[1] - Support frame for flat roof installation (45° to horizontal) of manufacturer was used during test at SPF.

2 Freeze resistance

Test in accordance with EN 12976-2, Chapter 5.1

Specification:	Flat plate collector with anti-freeze fluid in the collector loop with the following specification: Water- / Propyleneglycol mixture Propyleneglycol, Antifrogen N
Measured after the system test:	Glycol concentration: approx. 33 vol. % Freeze resistance: approx. -20 °C
Test result	No major failure
Remarks	None
Date of test	21.09.2016

3 Over temperature protection

Test in accordance with EN 12976-2, Chapter 5.2

Inclination of collector plane:	--
Type of over temperature protection:	--
Test procedure:	Outdoor test according to chapter 5.2.3 of EN 12976
Number of days	--
Test result	Not tested
Remarks	The system was tested as “medium” subtype according to the Solar Keymark Scheme Rules for system families. The over temperature protection was tested on S248; see test report S248QPEN.
Date of test	--

4 Pressure resistance

Test in accordance with EN 12976-2, Chapter 5.3

Draw-off loop Date of test: 22.07.2016 /13.09.2016

Working pressure [bar]		10.0	
		Test pressure [bar]	Test duration [min]
	Pressure at begin of test	15.0 / 15.0	15 / 16
	Pressure at end of test	15.0 / 15.0	

Collector loop Date of test: 22.07.2016 /13.09.2016

Working pressure [bar]	3.0

	Test pressure [bar]	Test duration [min]
Pressure at begin of test	4.5 / 4.6	15 / 15
Pressure at end of test	4.5 / 4.5	

Remarks	Pressure resistance test before and after the performance measurement.
Test result	13.09.2016

5 Water contamination

Test in accordance with EN 12976-2, Chapter 5.4

Test result	No major failure
Remarks	None
Date of test	03.08.2010

6 Safety equipment

Test in accordance with EN 12976-2, Chapter 5.6

Safety valves	Comply with the requirements according to EN 12976:2006
Safety and expansion lines	Not required
Blow-off lines	The blow-off lines for the T,p-safety valve are not delivered as part of the system. The manufacturer states in the installation manual that blow-off lines need to be connected to the safety valves. The blow-off lines shall be arranged in such a way that no risk for people, materials and environment could occur.
Test result	No major failure
Remarks	None
Date of test	25.08.2010

7 Labelling

Test in accordance with EN 12976-2, Chapter 5.7

Labelling of the Solar heating system

Place of label plate	Collector and storage tank
Labelling	The label contains all major information required in EN12976:2006
Test result	No major failure
Remarks	None
Date of test	24.08.2010

8 Thermal performance characterisation

The performance and reference conditions are in accordance with EN 12976-2 chapter 5.8
Test method: ISO/DIS 9459-5:1997

8.1 Description of the measured data

The solar radiation is an average value of the solar irradiation in the collector plane. For a valid day, the irradiation in the collector plane shall exceed 12 MJ/m^2 during this day. The ambient air temperature is an average value measured close to the collector array.

$S_{sol}A$: The aim is to acquire information about collector array performance at high efficiencies. The draw-offs specified are designed to keep the collector inlet cold.

$S_{sol}B$: The aim is to acquire information about store heat loss and collector array performance at low efficiencies. The draw-offs are specified are designed to allow the system to become as hot as possible for as long as possible. Overheating of the store is avoided.

S_{sto}: The test sequence is to identify the overall store losses. The store is heated up by sun for two consecutive days. Subsequently the collectors are covered and no draw-offs are specified for 36 to 48 hours.

S_{aux}: This sequence is intended to determine the heat losses and the volume fraction of the auxiliary heated portion of the store.

Sequence number	1	2	3	4
Sequence type	$S_{sol}A$	$S_{sol}B$	S_{sto}	S_{aux}
Solar radiation [W/m^2]	282.6	194.6	134.5	n/a
Ambient air temperature [°C]	23.1	20.3	19.9	n/a
Start date	28.07.2016	31.07.2016	03.08.2016	n/a
Number of days	3	3	4	n/a
Number of valid days	3	3	2	n/a

8.2 System Parameters

Determined according to the test method ISO/DIS 9459-5

Effective collector area	A_C*	2.287	m^2
Effective collector loss coefficient	u_C*	7.869	W m^{-2} K^{-1}
Total store heat loss coefficient	U_S	3.212	W/K
Total store heat capacity	C_S	1.364	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	0.06514	-
Stratification parameter	S_C	0.266	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W
Wind speed dependence of u_C*		n/a	
Wind option used		W_{ignore}	
Wind correction used		n/a	
Effective store volume		326	l

8.3 Annual performance prediction in accordance with EN 12976-2 for European locations

Q_d Heat demand.
Q_L Heat delivered by the solar heating system (load).
f_{sol} Solar fraction: the energy supplied by the solar part of the system divided by the total system load.
Q_{par} Parasitic energy (electricity) e.g. for pump, controller etc.

Performance indicators for solar-only and solar preheat systems on annual base for a demand volume of **140 l/d**

Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59.6° N)	7821	4630	59.2	0
Würzburg (49.5° N)	7506	4683	62.4	0
Davos (46.8° N)	8483	6973	82.2	0
Athens (38.0° N)	5834	5391	92.4	0

Performance indicators for solar-only and solar preheat systems on annual base for a demand volume of **170 l/d**

Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59.6° N)	9492	5325	56.1	0
Würzburg (49.5° N)	9114	5395	59.2	0
Davos (46.8° N)	10281	7947	77.3	0
Athens (38.0° N)	7064	6322	89.5	0

Performance indicators for solar-only and solar preheat systems on annual base for a demand volume of **200 l/d**

Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59.6° N)	11164	5928	53.1	0
Würzburg (49.5° N)	10691	6030	56.4	0
Davos (46.8° N)	12110	8816	72.8	0
Athens (38.0° N)	8326	7210	86.6	0

Performance indicators for solar-only and solar preheat systems on annual base for a demand volume of **250 l/d**				
Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59.6° N)	13939	6760	48.5	0
Würzburg (49.5° N)	13371	6940	51.9	0
Davos (46.8° N)	15137	9915	65.5	0
Athens (38.0° N)	10406	8481	81.5	0

Performance indicators for solar-only and solar preheat systems on annual base for a demand volume of **300 l/d**				
Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59.6° N)	16746	7335	43.8	0
Würzburg (49.5° N)	16052	7641	47.6	0
Davos (46.8° N)	18165	10645	58.6	0
Athens (38.0° N)	12488	9529	76.3	0

Performance indicators for solar-only and solar preheat systems on annual base for a demand volume of **400 l/d**				
Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59.6° N)	22327	7882	35.3	0
Würzburg (49.5° N)	21413	8330	38.9	0
Davos (46.8° N)	24220	11238	46.4	0
Athens (38.0° N)	16651	12073	72.5	0

8.4 Remarks on the test procedure

The system model NATURAL SOL 230 V2 with the SPF test number S248 was tested as the “medium” system subtype of the system family. The determination of the annual performance data for the system subtypes of the same system family have been extrapolated using the performance data of this medium system. The annual performance data for the system subtypes are reported in APPENDIX B.

9 Reverse flow protection

Test in accordance with EN 12976-2, Chapter 5.10

Test result	No major failure
Remarks	None
Date of test	21.09.2016

10 Electrical safety

Test in accordance with EN 12976-2, Chapter 5.11

Test result	--
Remarks	The system does not contain any electrical devices.
Date of test	21.09.2016

11 Remarks

The applied test methods meet the requirements of the European Standard EN 12976-2:2006, “Thermal solar systems and components – Factory made systems – Part 2: Test methods“. The thermal performance of the system is carried out according to ISO/DIS 9459-5:1997.

This report may not be copied except in full.
This test report refers only to the tested system.
This test report is issued according to the requirements of EN 12976 and ISO 17025.

Rapperswil, 20.06.2018

Dr. Andreas Bohren
Head of SPF-Testing

Ozan Türk
Test engineer

Appendix A: Summary

System test according to EN 12976

Test	Results
Freeze resistance	Passed
Over temperature protection	Not tested, see S248QPEN
Pressure resistance	Passed
Water contamination	Passed
Safety equipment	Passed
Labelling	Passed
Thermal performance characterisation	See chapter 8
Reverse flow protection	Passed
Electrical safety	Not applicable

Appendix B: System Family according to Solar Keymark

The definition of a System Family is in accordance with the Specific CEN Keymark Scheme Rules for Solar Thermal Products[2]. The defined System Family fulfils the requirmentes for grouping different system configurations into one system family.

Specification of collector(s)

Modell	Solar Keymark Register No.	A_a [m^2]	η_{0a} [-]	a_{1a} [$W/(m^2K)$]	a_{2a} [$W/(m^2K)$]	K_{50} [-]
ARIS2004	011-7S494 F	1.91	0.777	4.35	0.0073	0.91
ARIS2504	011-7S494 F	2.30	0.777	4.35	0.0073	0.91

Summary of the System Family

System model	Storage Volume [l]	Collector Model	No. of Modules	A_a of system	A/V-ratio		System (Sub)type
NATURAL SOL 150 V2	160	ARIS2004	1	1.91	0.01194		S249 ST1
NATURAL SOL 151 V2	160	ARIS2504	1	2.30	0.01438		S249 ST2
NATURAL SOL 200 V2	200	ARIS2004	1	1.91	0.00955		S249 ST3
NATURAL SOL 228 V2	200	ARIS2504	1	2.30	0.01475		S249 ST4
NATURAL SOL 230 V2	200	ARIS2004	2	3.81	0.01907	H	S249 ST5
NATURAL SOL 280 V2	300	ARIS2004	2	3.81	0.01271	M	S249
Average A/V-ratio of the system family					0.01319		

M – medium system: reference system to dermine the thermal performance of the system subtypes
H – system with the highest ratio of collector aperture area to total store volume (A/V-ratio)

Parameters to determine annual performance of Subsystems

System (Sub)type	$U_{loop,tot}$ [W/K]	U_{hx} [$W/(Km^2)$]	A_{hx} [m^2]	$A_{ref,surface}$ [m^2]	$A_{x,surface}$ [m^2]	Test Report
S248	1.095	200	1.94	3.673	--	S249EN
S248 ST1	0.780	200	0.87	--	2.396	S249EN
S248 ST2	0.845	200	0.87	--	2.396	S249EN
S248 ST3	0.780	200	1.24		4.036	S249EN
S248 ST4	0.845	200	1.24		4.036	S249EN

[2] Homepage of Solar Keymark, URL: www solarkeymark.org

S248 ST5	1.008	200	1.24		4.036	S249EN, S248QPEN

Nomenclature

η_{0a}	Collector efficiency based on aperture area
a_{1a}	Collector heat loss coefficient based on aperture area
a_{2a}	Collector temperature dependence of the heat loss coefficient based on aperture area
A_{hx}	Total surface area of heat exchanger
$A_{ref,surface}$	Surface area of store in the reference configuration (medium system)
$A_{x,surface}$	Surface area of store in the corresponding configuration (subtype)
A/V-ratio	Ratio of collector aperture area to total store volume
A_a	Collector aperture area
K_{50}	Incident angle modifier at 50°
U_{hx}	Heat transfer coefficient per m^2 of the heat exchanger
$U_{loop,total}$	Total heat transfare coefficient of the collector loop piping

B.1 Comparison of annual performance for the reference system using “free” and “fixed” collector parameters

The performance indicators and the annual performance prediction for the system subtypes which are not performance tested can be determined based on the test results of the “medium” subtype. The procedure is described in the Specific CEN Keymark Scheme Rules for Solar Thermal Products.

To determine the performance indicators **Method II (DST)** is used in accordance with the Solar Keymark – Specific Scheme Rules, ANNEX D.

System parameters of the reference system use the “fixed” collector parameters. The “fixed” collector parameters are calculated according ANNEX D of the Specific Solar Keymark Scheme Rules.

Effective collector area	A_C*_F	1.088	m^2
Effective collector loss coefficient	u_C*_F	8.606	W m^{-2} K^{-1}
Total store heat loss coefficient	$U_{s,ref,fix}$	1.369	W/K
Total store heat capacity	$C_{s,ref,fix}$	0.554	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	2.061	-
Stratification parameter	S_C	0.2698	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W

Comparison of the annual performance using the two sets of system parameters for the tested reference system (“medium” system).

daily load volume	Location	Q_d	Q_L free parameters	Q_L fixed collector parameters	Error of prediction
		MJ	MJ	MJ	%
140 l/d	Stockholm	7821	4630	4622	0.2%
	Würzburg	7506	4683	4653	0.6%
	Davos	8483	6973	6965	0.1%
	Athens	5834	5391	5397	-0.1%
170 l/d	Stockholm	9492	5325	5354	-0.5%
	Würzburg	9114	5395	5377	0.3%
	Davos	10281	7947	7978	-0.4%

	Athens	7064	6322	6344	-0.3%
200 l/d	Stockholm	11164	5928	5995	-1.1%
	Würzburg	10691	6030	6062	-0.5%
	Davos	12110	8816	8937	-1.4%
	Athens	8326	7210	7268	-0.8%
250 l/d	Stockholm	13939	6760	6900	-2.0%
	Würzburg	13371	6940	7047	-1.5%
	Davos	15137	9915	10203	-2.8%
	Athens	10406	8481	8617	-1.6%
300 l/d	Stockholm	16746	7335	7485	-2.0%
	Würzburg	16052	7641	7833	-2.5%
	Davos	18165	10645	11099	-4.1%
	Athens	12488	9529	9753	-2.3%
400 l/d	Stockholm	22327	7882	8284	-4.9%
	Würzburg	21413	8330	8779	-5.1%
	Davos	24220	11238	12013	-6.5%
	Athens	16651	12073	11439	5.5%

Test result	Determination of performance indicators possible
Remarks	None
Date of test	15.11.2016

B.2 Determination of the annual performance for the system subtypes

B.2.1 Annual performance prediction for S249 ST1

Differences to the “medium” system

System model:	NATURAL SOL 150 V2
Design load:	150 l/d

Collector

Model name:	ARIS2004
Number of collector modules:	1

Storage tank

Model name:	SV160
Volume:	160 l
Outside diameter:	580 mm
Insulation thickness:	40 mm

Back-up part of storage:

Volume:	n.a.
Recommende set temperature:	n.a.

Connecting piping between the collector(s) and the tank

Diameter:	DN16, corrugated pipe
Length:	2.4 m
Insulation thickness:	9 mm

Comments on sub system

None

System Parameters

Effective collector area	A_C*	1.342	m^2
Effective collector loss coefficient	u_C*	7.175	W m^{-2} K^{-1}
Total store heat loss coefficient	$U_{S,x}$	2.653	W/K
Total store heat capacity	$C_{S,x}$	0.681	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	0.205	-
Stratification parameter	S_C	0.177	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W
Wind speed dependence of u_C*		n/a	
Wind option used		W_{ignore}	
Wind correction used	n/a		

daily load volume	Location	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
80 l/d	Stockholm	4478	2387	53.3	0
	Würzburg	4289	2410	56.2	0
	Davos	4857	3550	73.1	0
	Athens	3343	2915	87.2	0
110 l/d	Stockholm	6150	2976	48.4	0
	Würzburg	5897	3037	51.5	0
	Davos	6654	4358	65.5	0
	Athens	4573	3731	81.6	0
140 l/d	Stockholm	7821	3386	43.3	0
	Würzburg	7506	3543	47.2	0
	Davos	8483	4954	58.4	0
	Athens	5834	4451	76.3	0
170 l/d	Stockholm	9492	3664	38.6	0
	Würzburg	9114	3892	42.7	0
	Davos	10281	5315	51.7	0
	Athens	7064	5015	71.0	0
200 l/d	Stockholm	11164	3829	34.3	0
	Würzburg	10691	4084	38.2	0
	Davos	12110	5534	45.7	0
	Athens	8326	5487	65.9	0
250 l/d	Stockholm	13939	4000	28.7	0
	Würzburg	13371	4238	31.7	0
	Davos	15137	5691	37.6	0
	Athens	10407	5942	57.1	0

B.2.2 Annual performance prediction for S249 ST2

Differences to the reference system

System model:	NATURAL SOL 151 V2
Design load:	150 l/d

Collector

Model name:	ARIS2504
Number of collector modules:	1

Storage tank

Model name:	SV160
Volume:	160 l
Outside diameter:	580 mm
Insulation thickness:	40 mm

Back-up part of storage:

Volume:	n.a.
Recommende set temperature:	n.a.

Connecting piping between the collector(s) and the tank

Diameter:	DN16, corrugated pipe
Length:	2.6 m
Insulation thickness:	9 mm

Comments on sub system

None

System Parameters

Effective collector area	A_C*	1.616	m^2
Effective collector loss coefficient	u_C*	7.117	$W\ m^{-2}\ K^{-1}$
Total store heat loss coefficient	$U_{S,x}$	2.653	W/K
Total store heat capacity	$C_{S,x}$	0.9851	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	0.205	-
Stratification parameter	S_C	0.1773	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W
Wind speed dependence of u_C*		n/a	
Wind option used		W_{ignore}	
Wind correction used	n/a		

daily load volume	Location	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
80 l/d	Stockholm	4478	2561	57.2	0
	Würzburg	4289	2569	59.9	0
	Davos	4857	3837	79.0	0
	Athens	3343	3029	90.6	0
110 l/d	Stockholm	6150	3229	52.5	0
	Würzburg	5897	3279	55.6	0
	Davos	6654	4791	72.0	0
	Athens	4573	3937	86.1	0

140 l/d	Stockholm	7821	3762	48.1	0
	Würzburg	7506	3880	51.7	0
	Davos	8483	5573	65.7	0
	Athens	5834	4761	81.6	0
170 l/d	Stockholm	9492	4167	43.9	0
	Würzburg	9114	4366	47.9	0
	Davos	10281	6127	59.6	0
	Athens	7064	5446	77.1	0
200 l/d	Stockholm	11164	4477	40.1	0
	Würzburg	10691	4725	44.2	0
	Davos	12110	6515	53.8	0
	Athens	8326	6044	72.6	0
250 l/d	Stockholm	13939	4739	34.0	0
	Würzburg	13371	5081	38.0	0
	Davos	15137	6872	45.4	0
	Athens	10407	6817	65.5	0

B.2.3 Annual performance prediction for S249 ST3

Differences to the "medium" system

System model: NATURAL SOL 200 V2
Design load: 200 l/d

Collector

Model name: ARIS2004
Number of collector modules: 1

Storage tank

Model name: SV200
Volume: 200 l
Outside diameter: 580 mm
Insulation thickness: 40 mm

Back-up part of storage:

Volume: n.a.
Recommende set temperature: n.a.

Connecting piping between the collector(s) and the tank

Diameter: DN16, corrugated pipe
Length: 2.4 m
Insulation thickness: 9 mm

Comments on sub system

None

System Parameters

Effective collector area	A_C*	1.342	m^2
Effective collector loss coefficient	u_C*	7.175	$W\ m^{-2}\ K^{-1}$
Total store heat loss coefficient	$U_{S,x}$	3.197	W/K
Total store heat capacity	$C_{S,x}$	0.851	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	0.205	-

Stratification parameter	S_C	0.177	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W
Wind speed dependence of u_C*		n/a	
Wind option used		W_{ignore}	
Wind correction used		n/a	

daily load volume	Location	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
110 l/d	Stockholm	6150	2878	46.8	0
	Würzburg	5897	2955	50.1	0
	Davos	6654	4185	62.9	0
	Athens	4573	3658	80.0	0
140 l/d	Stockholm	7821	3316	42.4	0
	Würzburg	7506	3468	46.2	0
	Davos	8483	4793	56.5	0
	Athens	5834	4381	75.1	0
170 l/d	Stockholm	9492	3626	38.2	0
	Würzburg	9114	3855	42.3	0
	Davos	10281	5223	50.8	0
	Athens	7064	4980	70.5	0
200 l/d	Stockholm	11164	3851	34.5	0
	Würzburg	10691	4105	38.4	0
	Davos	12110	5522	45.6	0
	Athens	8326	5503	66.1	0
250 l/d	Stockholm	13939	4056	29.1	0
	Würzburg	13371	4359	32.6	0
	Davos	15137	5813	38.4	0
	Athens	10407	6088	58.5	0
300 l/d	Stockholm	16746	4220	25.2	0
	Würzburg	16052	4478	27.9	0
	Davos	18165	5958	32.8	0
	Athens	12488	6369	51.0	0

B.2.4 Annual performance prediction for S249 ST4

Differences to the "medium" system

System model: NATURAL SOL 228 V2
Design load: 200 l/d

Collector

Model name: ARIS2504
Number of collector modules: 1

Storage tank

Model name: SV200
Volume: 200 l
Outside diameter: 580 mm
Insulation thickness: 40 mm

Back-up part of storage:

Volume:	n.a.
Recommende set temperature:	n.a.

Connecting piping between the collector(s) and the tank

Diameter:	DN16, corrugated pipe
Length:	2.6 m
Insulation thickness:	9 mm

Comments on sub system

None

System Parameters

Effective collector area	A_C*	1.616	m^2
Effective collector loss coefficient	u_C*	7.117	W m^{-2} K^{-1}
Total store heat loss coefficient	$U_{S,x}$	3.197	W/K
Total store heat capacity	$C_{S,x}$	0.851	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	0.205	-
Stratification parameter	S_C	0.177	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W
Wind speed dependence of u_C*		n/a	
Wind option used		W_{ignore}	
Wind correction used	n/a		

daily load volume	Location	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
110 l/d	Stockholm	6150	3155	51.3	0
	Würzburg	5897	3202	54.3	0
	Davos	6654	4651	69.9	0
	Athens	4573	3878	84.8	0
140 l/d	Stockholm	7821	3684	47.1	0
	Würzburg	7506	3805	50.7	0
	Davos	8483	5438	64.1	0
	Athens	5834	4702	80.6	0
170 l/d	Stockholm	9492	4091	43.1	0
	Würzburg	9114	4293	47.1	0
	Davos	10281	5983	58.2	0
	Athens	7064	5383	76.2	0
200 l/d	Stockholm	11164	4387	39.3	0
	Würzburg	10691	4650	43.5	0
	Davos	12110	6382	52.7	0
	Athens	8326	5986	71.9	0
250 l/d	Stockholm	13939	4670	33.5	0
	Würzburg	13371	5001	37.4	0
	Davos	15137	6751	44.6	0
	Athens	10407	6754	64.9	0

300 l/d	Stockholm	16746	4856	29.0	0
	Würzburg	16052	5153	32.1	0
	Davos	18165	6939	38.2	0
	Athens	12488	7218	57.8	0

B.2.5 Annual performance prediction for S249 ST5

Differences to the "medium" system

System model: NATURAL SOL 230 V2
Design load: 200 l/d

Collector

Model name: ARIS2004
Number of collector modules: 2

Storage tank

Model name: SV200
Volume: 200 l
Outside diameter: 580 mm
Insulation thickness: 40 mm

Back-up part of storage:

Volume: n.a.
Recommende set temperature: n.a.

Connecting piping between the collector(s) and the tank

Diameter: DN16, corrugated pipe
Length: 3.1 m
Insulation thickness: 9 mm

Comments on sub system

None

System Parameters

Effective collector area	A_C*	2.685	m^2
Effective collector loss coefficient	u_C*	6.969	W m^{-2} K^{-1}
Total store heat loss coefficient	$U_{S,x}$	3.197	W/K
Total store heat capacity	$C_{S,x}$	0.851	MJ/K
Fraction of the store used for auxiliary heating	f_{aux}	n/a	-
Mixing constant	D_L	0.205	-
Stratification parameter	S_C	0.177	-
Thermal resistance of load heat exchanger	R_L	n/a	K/W
Wind speed dependence of u_C*		n/a	
Wind option used		W_{ignore}	
Wind correction used	n/a		

daily load volume	Location	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
110 l/d	Stockholm	6150	3764	61.2	0
	Würzburg	5897	3739	63.4	0
	Davos	6654	5609	84.3	0
	Athens	4573	4271	93.4	0

140 l/d	Stockholm	7821	4528	57.9	0
	Würzburg	7506	4541	60.5	0
	Davos	8483	6804	80.2	0
	Athens	5834	5321	91.2	0

170 l/d	Stockholm	9492	5192	54.7	0
	Würzburg	9114	5268	57.8	0
	Davos	10281	7793	75.8	0
	Athens	7064	6245	88.4	0

200 l/d	Stockholm	11164	5749	51.5	0
	Würzburg	10691	5869	54.9	0
	Davos	12110	8622	71.2	0
	Athens	8326	7093	85.2	0

250 l/d	Stockholm	13939	6384	45.8	0
	Würzburg	13371	6686	50.0	0
	Davos	15137	9582	63.3	0
	Athens	10407	8263	79.4	0

300 l/d	Stockholm	16746	6832	40.8	0
	Würzburg	16052	7175	44.7	0
	Davos	18165	10045	55.3	0
	Athens	12488	9191	73.6	0

Appendix C: Reference conditions for performance presentation

in accordance with EN 12976-2

Reference conditions for system performance

Collector tilt angle	45°
Collector orientation	South
Draw-off flow rate	10 dm^3/min
Daily load volume	50 to 600 litres per day
Daily load pattern	100 % at 6 h after solar noon
Desired temperature T_D (if the temperature exceeds T_D, cold water will be mixed to reach T_D.)	45°C
Cold water supply temperature	s. the following table
Store ambient temperature For systems where the store is located outside, the ambient temperature from the climate data shall be used.	15°C
Temperature of integrated auxiliary heating	52.5°C

Data for calculation of the cold water temperature and the energy of solar radiation received in the collector array over one year at the reference locations.

	Data correspond to EN 12976-2			
	Average cold water supply temperature [°C]	Amplitude [K]	Solar radiation [kWh m^{-2} a^{-1}]	Ambient temperature [°C]
Athens	17.8	7.4	1718	18.5
Davos	5.4	0.8	1684	3.2
Stockholm	8.5	6.4	1157	7.5
Würzburg	10.0	3.0	1230	9.0