FORSCHUNGS- UND TESTZENTRUM
FÜR SOLARANLAGEN
STUTTGART

Institut für Thermodynamik und Wärmetechnik
Universität Stuttgart

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itw

Test Report
Thermal Performance of Solar Collector

acc. to EN 12975-2: 2001

Test Report No.: 03COL325

Stuttgart, November 6th, 2003

Client:	**SUNRIKS Solar Products** **POB 4 8414MK Nieuwehorne** **Holland**
Manufacturer:	**Sunriks – ELRAM Solar Energy** **Systems Ltd - Israel**
Brand name:	**MARIS S10**
Year of production:	**2003**

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1 General Specifications (acc. to manufacturer)

Manufacturer

	Sunriks – ELRAM Solar Energy Systems Ltd Israel
contact person:	Mr. Shuki Veenstra SUNRIKS Solar Products POB 4 8414MK Nieuwehorne Holland E-Mail: info@sunriks.com
brand name:	MARIS S10
serial no. :	not specified
serial product or prototype:	serial product
year of production:	2003

Dimensions of collector unit

	determined by test laboratory
gross area:	2.33 m^2
aperture area:	2.16 m^2
absorber area:	2.13 m^2

Technical Figures

collector type:	flat plate collector
length:	1910 mm (determined by test lab.)
width:	1218 mm (determined by test lab.)
height:	86 mm (determined by test lab.)
materials:	frame aluminium
weight:	42 kg
insulation material:	EPDM
collector mounting:	roof mounting

Absorber

material:	copper
thickness:	0.2 mm
surface treatment:	selective coating
absorptance:	0.95
emittance:	0.1
heat transfer fluid content:	4.5 liters
flow pattern:	10 tubes parallel
dimensions absorber tubes:	15.85 mm x 0.8 mm
number of absorber tubes:	10
distance between absorber tubes:	110 mm
dimensions of the header:	19.0 mm x 0.98 mm
no. of connections:	4
dimension of connections:	3/4” inside thread

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Transparent Cover

number:	1
material:	low iron glass
manufacturer:	AFG
brand name:	Solite Solar Glass
transmittance:	0.91
thickness:	4 mm

Thermal Insulation

material:	Polyurethane foam, CFC-free
thermal conductivity:	0.025 W/(m K)
heat capacity:	not specified
density:	40-45 kg/m³
thickness:	26 mm

Limitations

stagnation temperature:	133°C
max. admissible operation pressure:	12 bar
allowed heat transfer medium:	Water, glycol, oil
nominal flowrate per collector:	30 – 60 kg/h

Ascertainment of collector

construction characteristics: Drawing No.:

- 150-10 for MARIS S10
- 120-07 for MARIS S7
- 200-10 for MARIS SL10

technical data sheets:

- AFG Glass, Solite Solar Glass

A list of used materials is missing.

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collector label:

The collector label shall moreover contain the following data:

- correct collector type
- serial number
- year of production
- gross area of collector
- stagnation temperature at 1000 W/m² and 30°C
- volume of heat transfer fluid
- net weight of the collector
- made in....

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 it is sold.

Validity

The test report is valid for the collector type MARIS S10 described above, the collector MARIS SL10 and the collector MARIS S7.

MARIS SL10 has an aperture area of 2.60 m² and 10 rising tubes.

MARIS S7 has an aperture area of 1.62 m² and 7 rising tubes.

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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	0.766
a_1 [W / (m²K)]	3.9998
a_2 [W / (m²K²)]	0.0135
incidence angle modifier $K_\theta(\theta)$ [-]	see page 9
effective heat capacity C [J/K]	42214
volume flowrate [l/(m²h)]	72
used heat carrier	water

Instantaneous efficiency curve (G* = 800 W/m²)

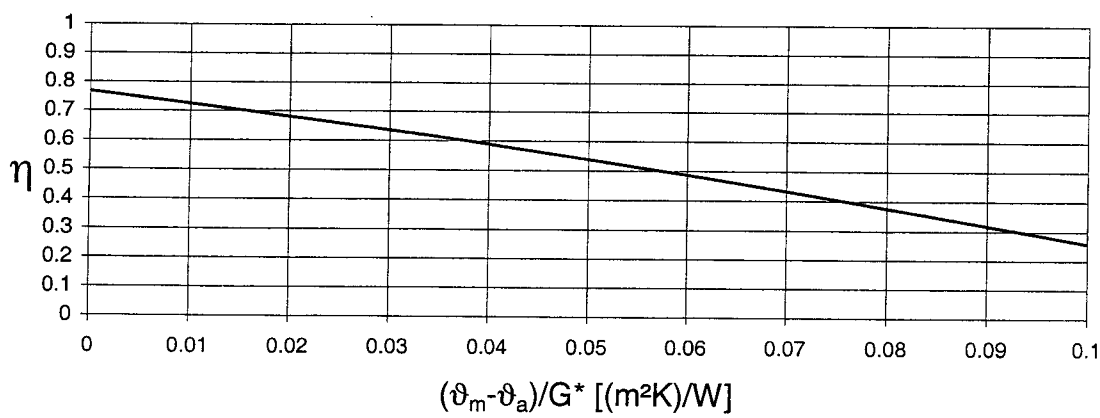

Table of efficiency (G* = 800 W/m²)

$(\vartheta_m-\vartheta_a)/G^*$ [(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	0.766	0.725	0.682	0.636	0.589	0.539	0.487	0.433	0.377	0.319	0.258

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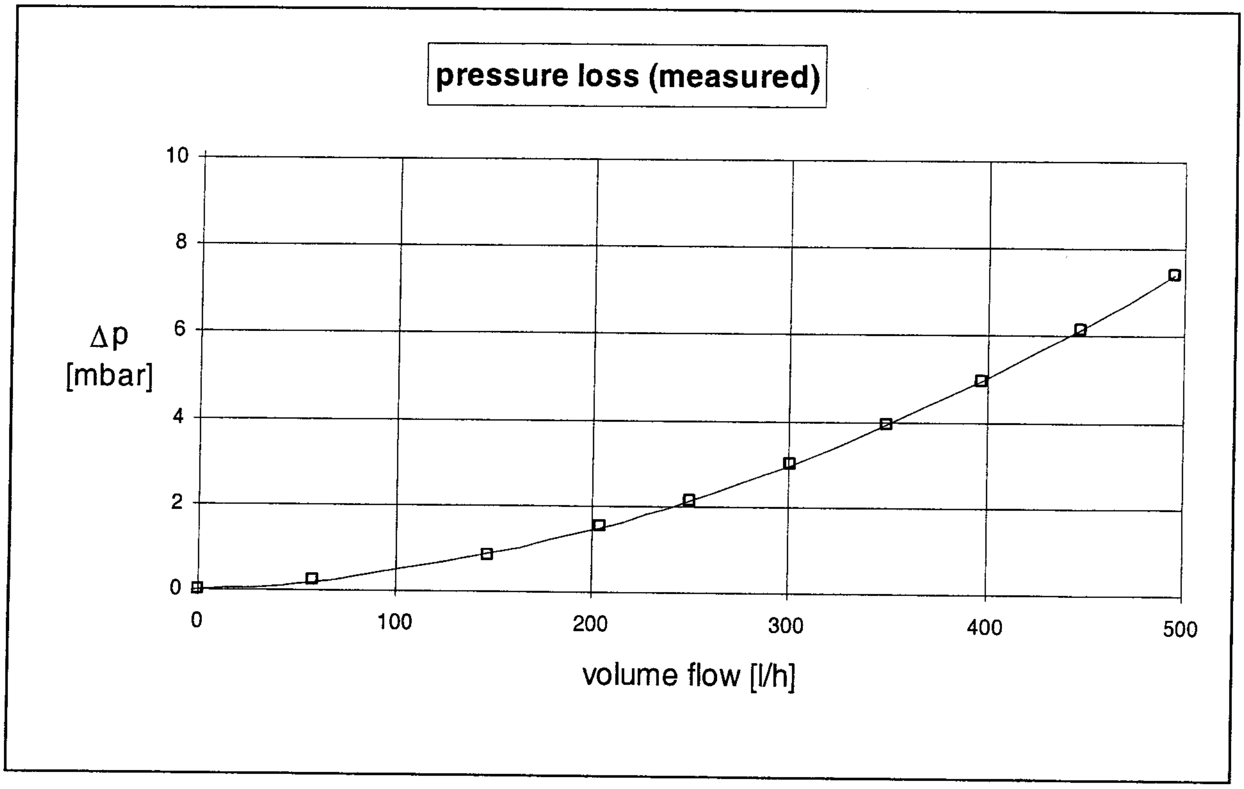
3 Pressure Loss Test Results

Determination of the pressure loss: $\Delta p = a \cdot \dot{V}^2 + b \cdot \dot{V}$

a [(mbar h²)/l²]	0.000026276
b [(mbar h)/l)]	0.001995882

(water temperature ϑ = 20°C ± 2°C)



volume flow [l/h]	0.0	58.2	146.8	203.9	250.2	300.6	349.9	397.7	447.5	495.0
pressure loss [mbar]	0.0	0.2	0.8	1.5	2.1	3.0	3.9	5.0	6.1	7.4

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4 Test Occurrences and Operating Behaviour

Nothing particular.

5 Test Methods

The outdoor test of the collector was carried out under quasi-dynamic 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:	August 15th 2003
test period:	August 19th to September 3rd 2003
test engineer:	Dipl.-Phys. M. Hampel

Stuttgart, November 6th 2003

i. V. Spindler

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 $\eta_0 =$ **0.766**	heat transfer coefficient $a_1 =$ **3.9998 W/(m²K)** $a_2 =$ **0.0135 W/(m²K²)**				area related heat capacity $c =$ **19.589 kJ/(m²K)**				
incidence angle modifier $K_{\theta d}$ **= 0.89**	Θ	0	10	20	30	40	50	60	70
	$K_{\theta b}(\Theta)=$	1.000	0.996	0.985	0.964	0.928	0.869	0.765	0.548

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, heat transfer capacity $(kA)_{WT}$ in [W/K]; $(kA)_{WT} = 9 \cdot A_c \cdot \vartheta_m^{0,6}$ A_c: aperture area [m²] ϑ_m: average value of heat exchanger inlet temperature and local storage temperature in [°C]
warm water consumption:	200 l/day (7^{00}: 80 l; 12^{00}: 40 l; 19^{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	410	495	539
4	372	450	489
5	340	**411**	446
6	312	374	406

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

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Annex B: Explanation upon the Measurements under quasi-dynamic Conditions

The collector parameters shown on page 6 are, according to EN 12975-2:2001, derived from the collector parameters gained from measurements under quasi-dynamic conditions

Used collector model

For evaluation of the measured data the area specific collector power was modelled according to the equation

$$\dot{q} = F'(\tau\alpha)_{en} K_{\Theta b}(\theta) G_b + F'(\tau\alpha)_{en} K_{\Theta d} G_d - c_1(\vartheta_m - \vartheta_a) - c_2(\vartheta_m - \vartheta_a)^2 - c_5 \frac{d\vartheta_m}{dt}$$

with

$$K_{\Theta b} = 1 - b_0 \left(\frac{1}{\cos\theta} - 1 \right)$$

Regression results

	based on the aperture area
$F'(\tau\alpha)_{en}$:	0.779 [-]
b_0:	0.235 [-]
$K_{\theta d}$:	0.937 [-]
c_1:	3.999 [W/(m²K)]
c_2:	0.014 [W/(m²K²)]
c_5:	19.585 [kJ/(m²K)]

Table of the incidence angle modifier of the direct solar irradiance

incident angle θ	0	10	15	20	30	40	50	60	70	90
$K_{\theta b}(\theta)$:	1.000	0.996	0.992	0.985	0.964	0.928	0.869	0.765	0.548	0.000

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Calculation of the collector parameters shown on page 6

η_0:	zero-loss collector efficiency (η_0 at ϑ_m-ϑ_a = 0) [-] $\eta_0 = F'(\tau\alpha)_{en} K_{\Theta b}(\theta = 15°) \cdot 0.85 + F'(\tau\alpha)_{en} K_{\Theta d} \cdot 0.15$
a_1:	heat loss coefficient [W/(m²K)] $a_1 = c_1$
a_2:	temperature dependence of the heat loss coefficient [W/(m²K²)] $a_2 = c_2$
$K_\Theta(50)$:	incident angle modifier for hemispherical solar irradiance [-] $K_\Theta(50) = \frac{K_{\Theta b}(50) \cdot 0.85 + K_{\Theta d} \cdot 0.15}{1 - 0.15 + K_{\Theta d} \cdot 0.15}$
C:	effective thermal capacity of the collector [J/K] $C = c_5 \cdot$ aperture area $\cdot$ 1000

Graphical presentation of the measured data (6 minutes mean values)

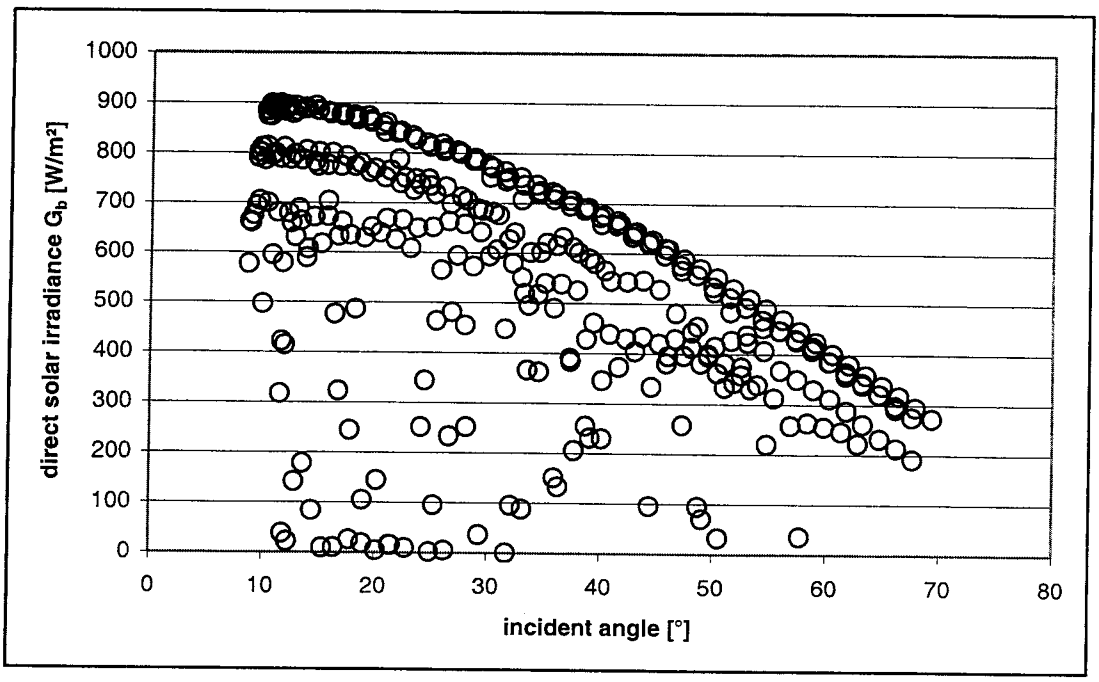

Figure B.1: the direct solar irradiance over the incident angle of the direct solar irradiance

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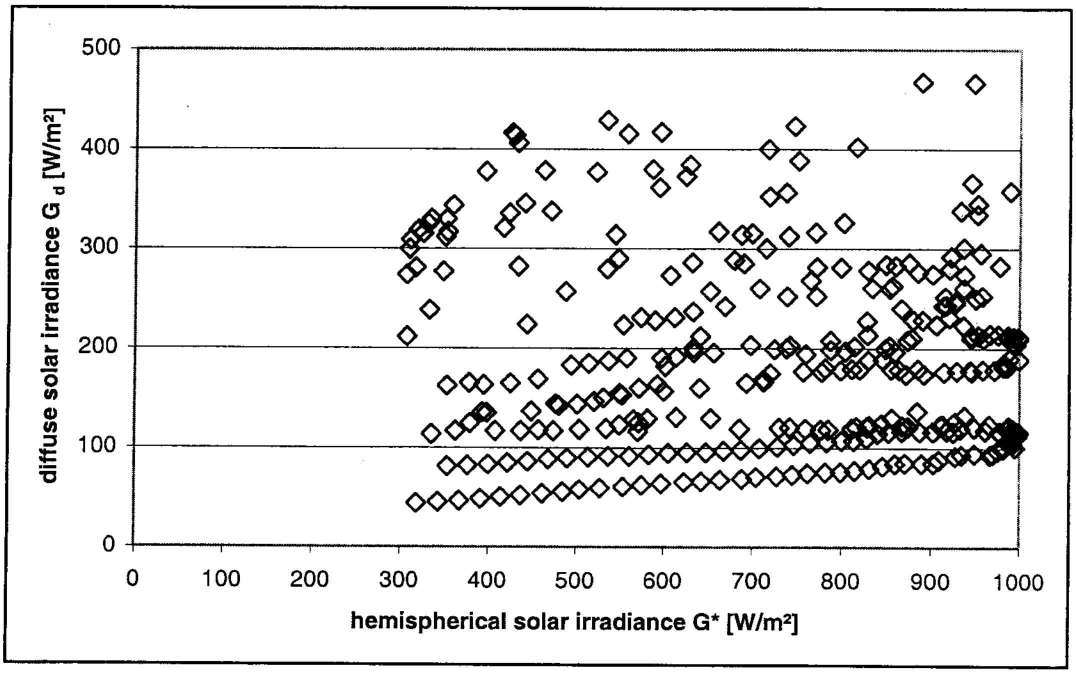

Figure B.2: diffuse solar irradiance over the total solar irradiance

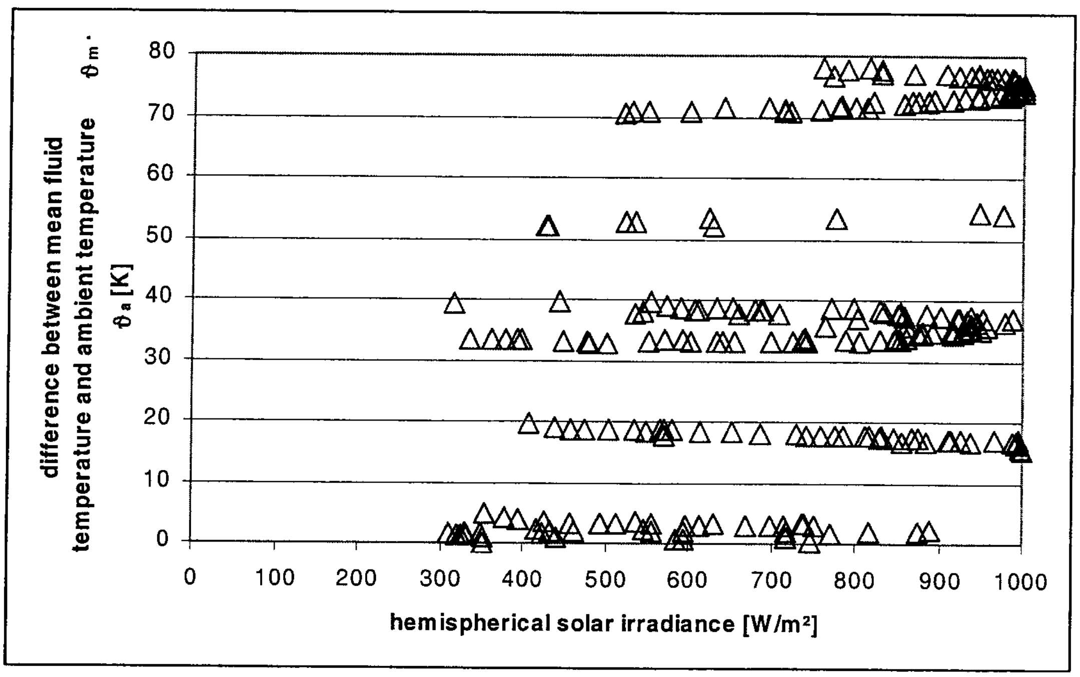

Figure B.3: difference between mean fluid temperature and ambient temperature over the hemispherical solar irradiance

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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]	effective thermal capacity of the collector
c	[kJ/(m² K)]	area based effective thermal capacity of the collector
c_1	[W/(m²K)]	heat loss coefficient
c_2	[W/(m²K²)]	temperature dependence of the heat loss coefficient
c_5	[kJ/(m²K)]	area based effective thermal capacity of the collector
F'	[-]	collector efficiency factor
G*	[W/m²]	hemispherical solar irradiance
G_b	[W/m²]	direct solar irradiance (beam irradiance)
G_d	[W/m²]	diffuse solar irradiance
$K_\theta(\theta)$	[-]	incident angle modifier for hemispherical solar radiation
$K_{\theta b}(\theta)$	[-]	incident angle modifier for direct solar radiation
$K_{\theta d}$	[-]	incident angle modifier for diffuse solar radiation
$(kA)_{WT}$	[W/K]	heat transfer capacity of the solar heat exchanger
$\dot{q}$	[W/m²]	area based useful power extracted from the collector
$\dot{V}$	[l/h]	volume flow rate of heat transfer fluid
Δp	[mbar]	pressure loss
η	[-]	collector efficiency
η_0	[-]	zero-loss collector efficiency (η_0 at $\vartheta_m - \vartheta_a = 0$)
λ	[W/(mK)]	heat conductivity
$(\tau\alpha)_{en}$	[-]	effective transmittance-absorptance product for direct solar radiation at normal incidence
ϑ	[°C]	temperature
ϑ_a	[°C]	ambient air temperature
ϑ_e	[°C]	collector outlet temperature of heat transfer fluid
ϑ_{in}	[°C]	collector inlet temperature of heat transfer fluid
ϑ_m	[°C]	mean temperature of heat transfer fluid
θ	[°]	incidence angle of the direct solar radiation