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Ein Unternehmen der Austrian Research Centers.

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Test Report

Project Designation

Determination of high temperature resistance,
efficiency, incidence angle modifier,
pressure drop and thermal capacity
of a covered solar collector
in new condition according to
ÖNORM EN 12975-2, chapter 6.1

Client

RIPOSOL Handels GmbH

Industriepark 12

A - 9330 Althofen

Order from / No 23 January 2004

Project number 2.04.00241.1.0 Test Engineer A. Montilla

Date of issue	translated edition: 23 Oct. 2006
Total number of issues / No	1 / 1
Number of pages	8
Annex: number of pages	7

The results relate exclusively to the terms tested.

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The German test report is used as a basis, if there are disagreements in translation.

Report of the Collector Test

General Information	
Report No.	**2.04.00241.1.0**
Date of new issue	translated edition: 23 October 2006
Receipt of test sample	18 February 2004
Test periode: (from/to)	16.04. - 02.07.2004
Name of Collector	**RP 200 VF Neu 2,1**
Type of Collector	flat plate collector
Serial product (y/n)	yes
Drawing number	* VF002
Serial number	32
Date of manufacturing	2004
Manufacturer	**Suntec Produktions GmbH**
Address	9330 Althofen, Industriepark
Phone, Fax	0043 (0)4262/37855-13
Distributed by	**Riposol Handels GmbH**
Address	9330 Althofen, Industriepark
Phone, Fax	0043 (0)4262/37855
Client	**Riposol Handels GmbH**
Testprocedure	Test according to EN 12975-2(Solar Keymark)
Indoor/Outdoor	steady state / indoor

Size, weight	
Length [mm]	2036
Width [mm]	1035
Height [mm]	103
Gross area A_G [m²]	2,107
Aperture area A_a [m²]	1,904
Absorber area A_A [m²]	1,850
Mass of collector (empty) [kg]	* 43

Frame Construction	
Casing: material	Aluminium anodised
Back board: material	Aluminium
Dimension [mm]	* 1000/2000/0,8
Material of sealing	* EPDM

Specifications	
recommended heat transfer fluid	* propylene glykol / water
rec. mixture (H_2O : x)	* 55% : 45%
rec. mass-flow [l/h]	* 55 - 160
rec. pressure [bar]	* 3,5
max. pressure [bar]	* 6
max. temperature [°C]	* 214
collector fluid content [l]	* 1,65

Cover	
Type and Name	*solar glass
Transmittance	* 0,914
Size [mm]	* 1000/2000/4
Structured ? (inside/outside)	inside

Absorber	
Coating (type and name)	* TiNOX
Absorptance	* 95 %
Emittance	* 5 %
Absorbersheet: material	copper plate
thickness [mm]	* 0,2
Connection Absorber - Piping	Ultrasonic welding
Piping: material	copper
dimension [mm]	* 10 x 0,5
Connection (harp or serpentine)	harp
Number of parallel served pipes	* 4
Number of serial served pipes	* 2
Connecting pipes: material	* copper
dimension [mm]	* 22 x 0,8

Insulation	
Material	* mineral wool
Specific mass [kg/m³]	* 40/50
Thickness [mm]	* 50

* = according to clients information

Results of Efficiency Testing

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Manufacturer	**Suntec Produktions GmbH**	Name of Collector	**RP 200 VF Neu 2,1**
Distributed by	**Riposol Handels GmbH**	Type of Collector	**flat plate collector**

Efficiency equation

$$\eta = \eta_0 - a_1 * (T_m - T_a) / G^* - a_2 * (T_m - T_a)^2 / G^*$$

Coefficients of the efficiency-equation

related to aperture area A_a

η_0	a_1	a_2
0,788	**4,274**	**0,003**

related to absorber area A_a

η_0	a_1	a_2
0,811	**4,399**	**0,003**

for G^*_{Norm} [W/m²] = 800

$(T_m - T_a) / G^*$	η bez. A_a	η bez. A_A
0	**0,788**	**0,811**
0,01	0,745	0,767
0,02	0,701	0,722
0,03	0,657	0,677
0,04	0,613	0,631
0,05	**0,568**	**0,585**
0,06	0,523	0,538
0,07	0,477	0,491
0,08	0,430	0,443
0,09	0,384	0,395
0,1	0,336	0,346

Performance [W]		Global solar radiation [W/m²]		
		400	700	1000
$t_m - t_a$ [K]	10	518	968	1418
	30	351	801	1251
	50	179	629	1079

Incident angle modifier
$K_{50°}$
0,89

Test conditions		
	global radiation G^*_{mean} [W/m²]	768
	G^*_{mean} at $K_{50°}$ - Measurement [W/m²]	644
	Mass flow [kg/h]	137,3
	Surrounding air velocity [m/s]	3 +/-1

Efficiency for $G^{*}_{Norm} = 800\ [Wm^{-2}]$

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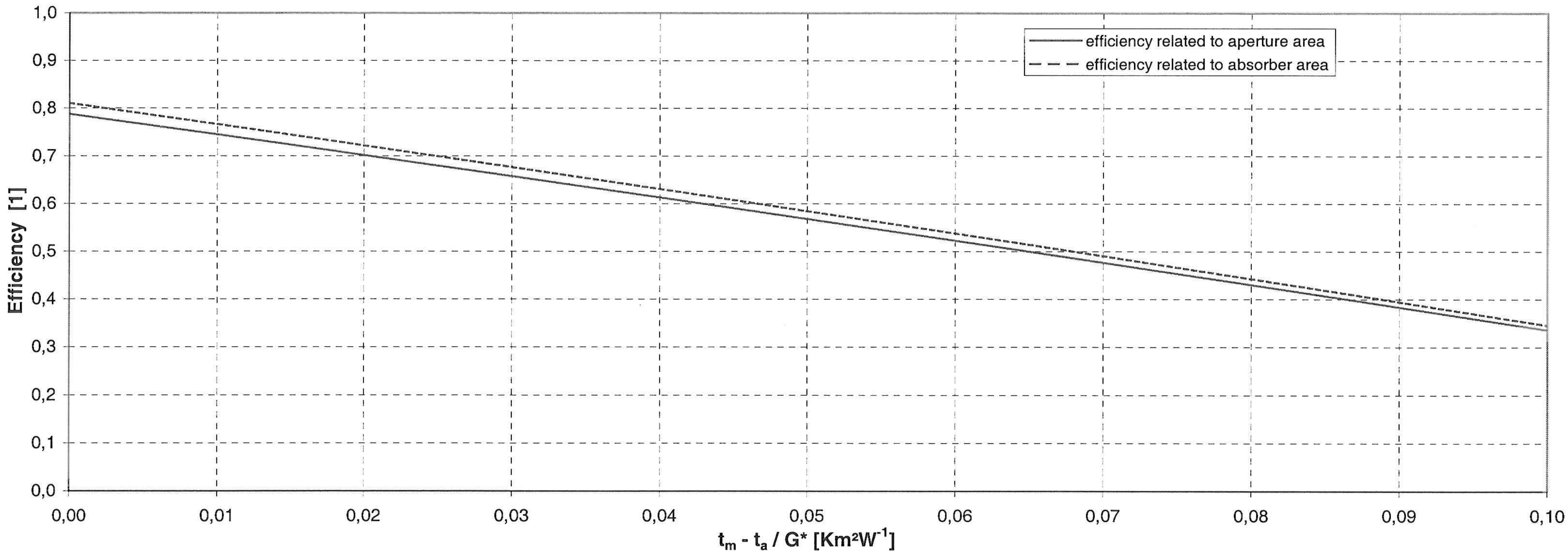
Aperture area [m²]	Absorber area [m²]	Mass flow [kg/h]	Surr.air velocity [m/s]
1,904	1,850	137	3 +/-1



Results of the Pressure Drop Measurement

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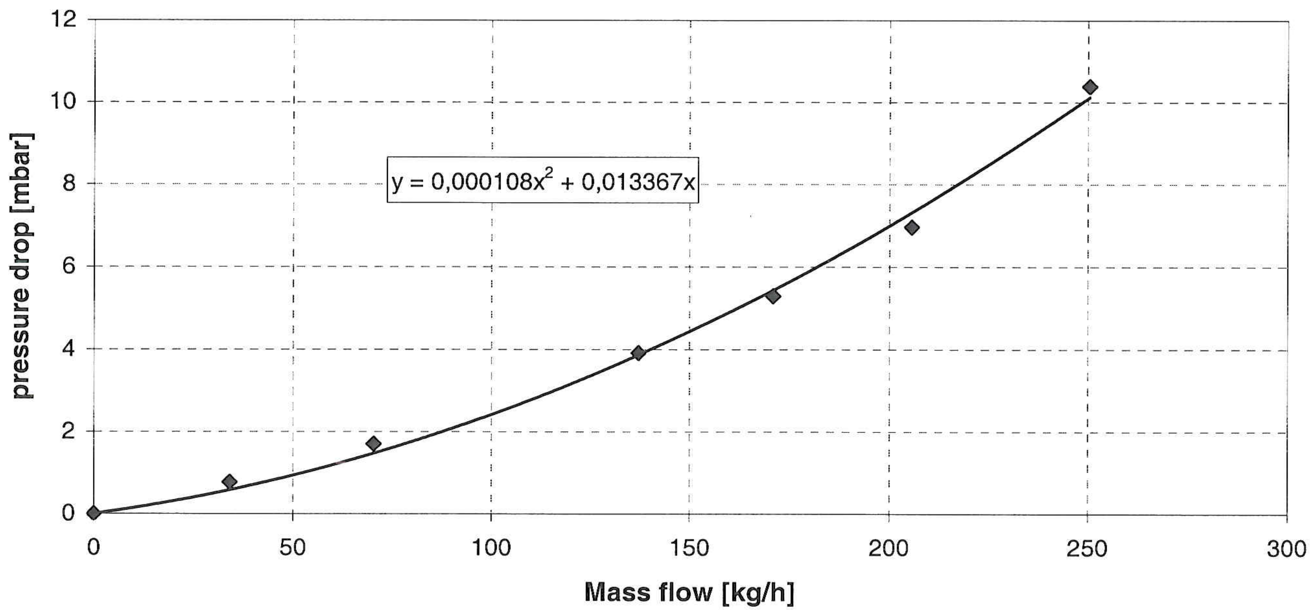
Distributed by	**Riposol Handels GmbH**	Type of Collector	**flat plate collector**

Measurement - No.	Volume flow [l/h]	Temp.fluid [°C]	Mass flow [kg/h]	Pressure [mbar]
1	0,00	20,90	0,00	0,00
2	34,19	20,92	34,13	0,77
3	70,46	20,56	70,33	1,71
4	137,40	20,52	137,16	3,92
5	170,95	20,51	170,65	5,29
6	205,94	20,50	205,58	6,96
7	250,84	20,49	250,40	10,39



Heat Capacity and High Temperature Resistance

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Manufacturer	**Suntec Produktions GmbH**	Name of Collector	**RP 200 VF Neu 2,1**
Distributed by	**Riposol Handels GmbH**	Type of Collector	**flat plate collector**

measured effective thermal capacity according EN 12975-2, annex J3: indoor test

effective thermal capacity of the collector [$J*K^{-1}$]	20015

effective thermal capacity based on the aperture area [$J*K^{-1}*m^{-2}$]	10512

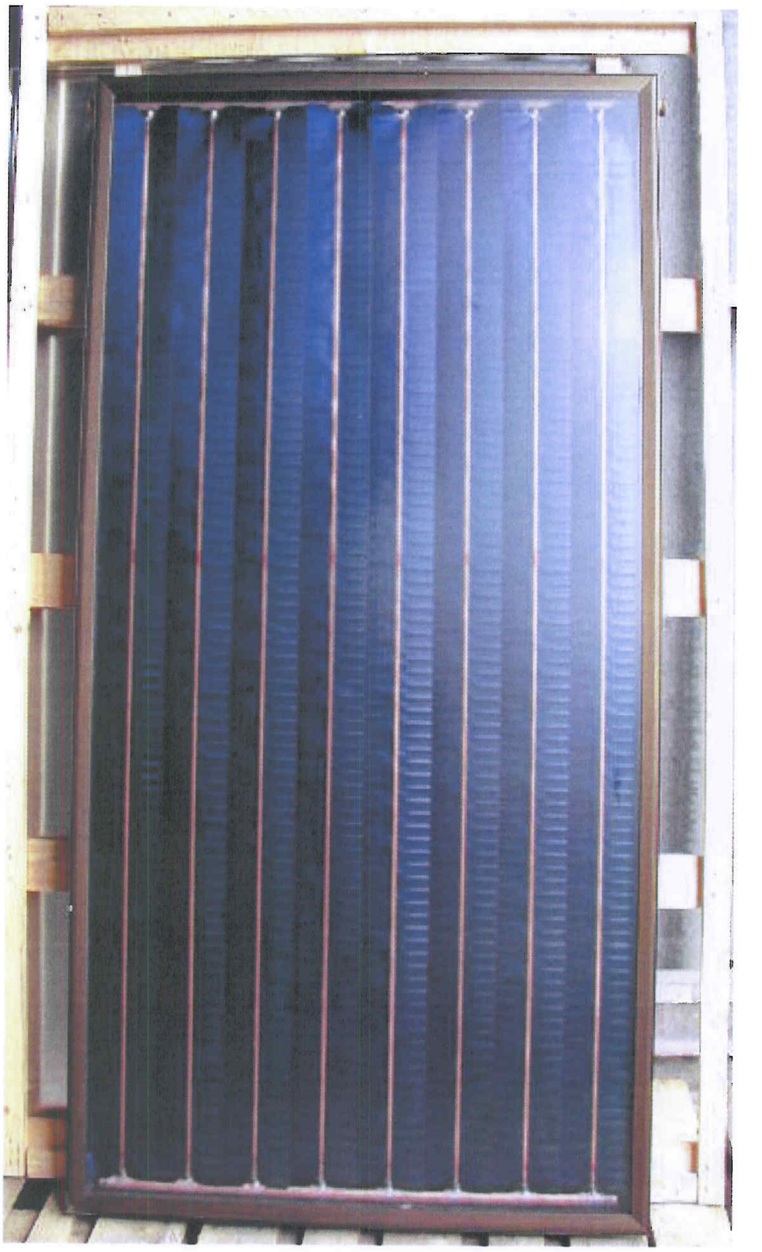
high temperature resistance testing	passed

approved signatory
Ing. Antonio Montilla

project manager
i.V.
DI (FH) Christian Buchbauer

head of Business Area
DI Hubert Fechner

Photograph of solar collector



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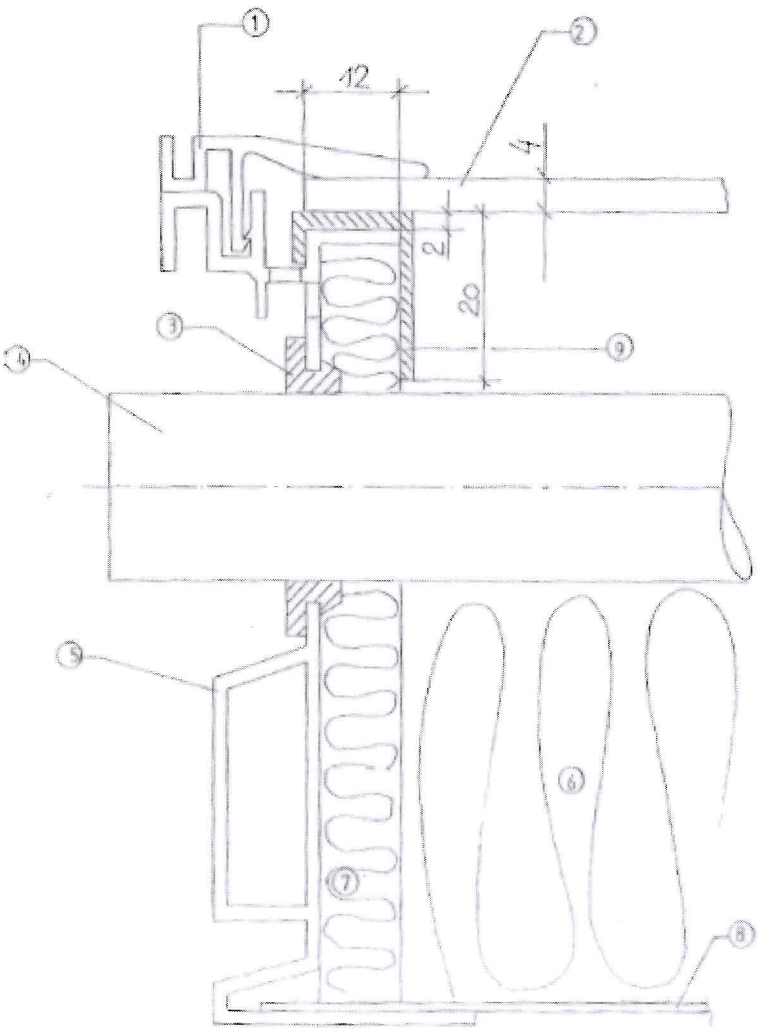
Schematic diagram of solar collector (according to clients´ information)

- 1 aluminium clamping profile
- 2 solar glass
- 3 flange
- 4 connecting pipe 22 / 0,8
- 5 aluminium frame profile
- 6 back side insulation 50 mm
- 7 side wall insulation
- 8 back side plate
- 9 EPDM sealing profile



Supplement for the report of the collector testing

This supplement is used for the information about the execution of collector testing with arsenal research as well as interpretation assistance of the available results.

1 Symbols and units

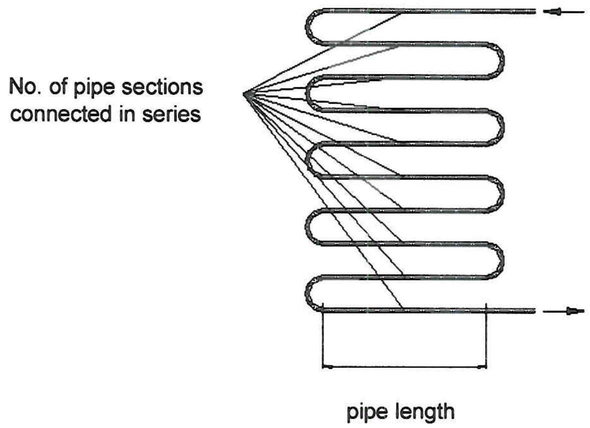
A_A	absorber area of collector [m^2]
A_a	aperture area of collector [m^2]
A_G	gross area of collector [m^2]
a_1	algebraic constant, reference to $T*_m$ [$Wm^{-2}K^{-1}$]
a_2	algebraic constant, reference to $T*_m$ [$Wm^{-2}K^{-2}$]
C	effective thermal capacity of collector [JK^{-1}]
c_i	specific thermal capacity of the collector components [$Jkg^{-1}K^{-1}$]
c_f	specific thermal capacity of heat transfer fluid [$Jkg^{-1}K^{-1}$]
$G*$	hemispherical solar irradiance [Wm^{-2}]
K_θ	incidence angle modifier [1]
$\dot{m}$	mass flowrate of heat transfer fluid [kgs^{-1}]
m_i	mass of collector components [kg]
p_i	weigthing factor
$\dot{Q}_{Nutz}$	useful power extracted from collector [W]
$\dot{Q}_{zu}$	power loss of collector [W]
t_a	ambient or surrounding air temperature [°C]
t_e	collector outlet (exit) temperature [°C]
t_i	collector inlet temperature [°C]
t_m	mean temperature of heat transfer fluid [°C]
v	surrounding air speed [ms^{-1}]
η	collector efficiency, with reference to $T*_m$ [1]

2 *Description of the tubing interconnecting*

To understand the information of the collector data sheet some examples are given.

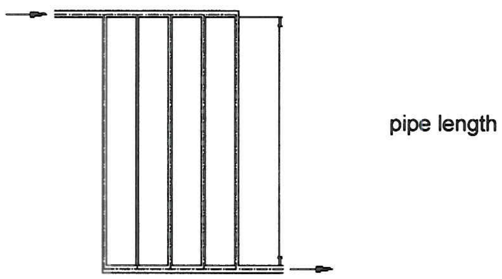
2.1 Connection type serpentine or "meander":

Piping connection: (harp or serpentine)	serpentine
No. of pipes connected in parallel	-
No. of pipe groups connected in series	10

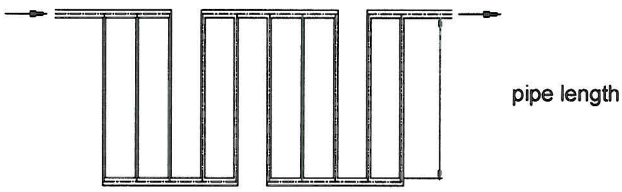


2.2 Connection type harp:

Piping connection: (harp or serpentine)	harp
No. of pipes connected in parallel	5
No. of pipe groups connected in series	-



Piping connection: (harp or serpentine)	harp
No. of pipes connected in parallel	3-2-3-2
No. of pipe groups connected in series	4



3 *Efficiency testing of collector*

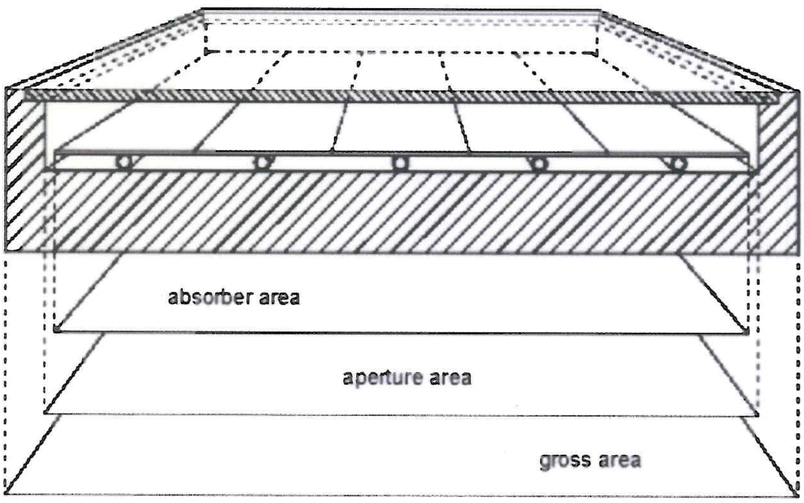
3.1 Determination of the coefficients of efficiency equation.

The instantaneous efficiency of a collector represents the relationship of the saved power by the heat transfer medium (=useful power extracted from collector) to the incidence (irradiation) power.

$$\eta = \frac{\dot{Q}_{Nutz}}{\dot{Q}_{zu}}$$

Useful power extracted from collector: $\dot{Q}_{Nutz} = \dot{m} \cdot c_f \cdot (t_e - t_i)$

To determine the power irradiated on to collector establish different areas can be taken as reference:



- Absorber area A_A [m^2] is designated as projection area of the absorber including those pipes, which are exposed to direct radiation.
- Aperture area A_a [m^2] is that area, where radiation is able to enter into the collector box. More exact definitions for different types of collectors are described in the responsible standard.
- The gross area A_G [m^2] represents the totally area of collector.

Different reference areas results in different efficiencies. According to the test regulation, the efficiency is referred to the absorber as well as to the aperture area. Since both have a significant meaning for the collector efficiency. Thus one calculates for example the irradiation on the aperture surface:

$$\dot{Q}_{zu} = A_a \cdot G*$$

Instantaneous efficiency results as:

$$\eta = \frac{\dot{Q}_{Nutz}}{\dot{Q}_{zu}} = \frac{\dot{m} \cdot c_f \cdot (t_e - t_i)}{A_a \cdot G*}$$

The dependence of the efficiency on the operating and site conditions can be mathematically represented through the steady-state test method by the following formula:

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

To determine the coefficients of this equation the efficiency values are measured at four different operating conditions:

- $t_m \approx t_a$
- With maximum operating temperature
- with at least two intermediate temperatures (distributed evenly over the operating range)

By means of a regression - according to the method of the smallest (mean) square error - the coefficients η_0, a_1, a_2 are calculated from the measured data, which can be seen in the listing of the results page. Different reference areas results - analogy to the efficiencies – in different coefficients.

3.2 Performance of collector

From the determined characteristic values the data of collector performance with different $(t_m - t_a)$-values and irradiance are calculated according to the standard, to illustrate the efficiency of the collector on the basis of absolute values.

3.3 Characteristic values and efficiency curve for G* = 800 [Wm^{-2}]

These characteristic values allow the direct comparison between the efficiency of different products. Out of this, the real capacity of a collector to convert radiation power into useful heat can be derived. This can be done along the whole range of operation. In order to give one more a clearer idea the well-known graphical representation in drawing the efficiency curve is chosen.

A typical efficiency value – for comparison purposes – is used at $\frac{(t_m - t_a)}{G*} = 0{,}05$. It reflects a real operating condition, in which a collector frequently is.

3.4 Incident angle modifier

The incident angle modifier shows the efficiency of a collector at variable angles of inclination. It shows the reduction of the efficiency with inclined irradiance relative to the efficiency with perpendicular irradiance.

$$K_\theta = \frac{\eta_0(\theta)}{\eta_0(0°)}$$

According to the standard, the incident angle modifier is determined for an angle of incidence of 50° ($K_{50°}$).

3.5 Test conditions

Angle of inclination of the collector	45° to horizontals
Heat transfer fluid	water
pressure in the hydraulic circuit	3 [bar]

3.6 Applied method

Indoor steady-state testing by solar simulator irradiation:

The irradiation equipment consists of metal halide lamps. To keep off the long wave IR radiation (λ > 3 μm) is used a double solar glass plate air-cooled. The upper side of the collector is therefore facing a cooled glass plate under ambient air temperature.

4 Determination of the Pressure Drop

The pressure drop between collector inlet and outlet is determined with varying flow rates (pressure loss). From these measured values - again by means of regression analysis - a curve and the associated mathematical function are determined, for calculating the expected pressure drop for any flow rate.

Test medium is again water. The mass flow is determined out of the measured flow rate and the density related to the fluid temperature.

5 Calculation of the effective thermal capacity of collector

The effective thermal capacity of the whole collector is determined according to ÖNORM EN 12975-2: 2002-12, Annex J3.

6 Metrology

6.1 Instrumentation

1 Pyranometer, No. 930113, I02; calibrated
1 Pyranometer, No. 930114, I03; calibrated
2 sensors for surrounding air temperature measurement; I05 and I06; calibrated
1 flowmeter, calibrated, consisting of:
Sensing element ; No.: A94 52 295, I04
Signal converter ;No.: A94 52 295
3 sensors for temperature measurement of heat transfer fluid I07, I08 and I09; calibrated
4 sensors for temperature measurement of the IR-radiation filter, I14 (1 to 4); calibrated
1 pressure drop meter, No. 102337, I19; calibrated
1 pressure drop meter, No. 100358, I20; calibrated
8 Current transformer, I23 (1 to 8); calibrated
Rotating vane anemometer, No: 35027; calibrated

6.2 Data acquisition system

Digital Meter/Logger, serial No. 6101307, I17; calibrated
Data Acquisition Unit, serial No. US37006760, I16; calibrated
PCI-GPIB Interface Card
IEEE-Bussystem and data processing by PC No. ARS 230, serial No. 02029913