

Ordered by:

Chromagen

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Test Report No. C1254LPAN

Tests according to
ISO 9806-1:1994, AS/NZS 2535.1:2007

Content:

	page
1 Description of Collector.....	2
1.1 Technical Data of Sample.....	2
1.2 Sketch of Collector.....	3
1.3 Specifications on Elements.....	3
1.4 Photo of Collector.....	4
1.5 Sketch of Collector Mounting.....	4
2 Test Methods and Results.....	5
2.1 Test of Thermal Performance.....	5
2.2 Incident Angle Modifier (IAM).....	13
2.3 Time Constant.....	14
2.4 Effective Thermal Capacity.....	14
2.5 Power Output per Collector Unit.....	14
2.6 Pressure Drop.....	15
3 Remarks.....	16

1 Description of Collector

1.1 Technical Data of Sample

Product information	
Manufacturer	Chromagen
Model	PR-F10
Type	Flat plate collector
Flow	Parallel grid
Serial product	Yes
Drawing number	--
Serial number	0100556194
Date of manufacture	01.05.2010

Physical parameters	
Gross length	2.187 m
Gross width	1.274 m
Gross height	0.090 m
Gross area	2.786 m ²
Aperture area	2.588 m ²
Absorber area	2.544 m ²
Weight empty	44.0 kg
Fluid capacity	4.8 l

Construction	
Type	Flat plate collector
Number of absorber elements	1
Absorber pitch	115.0 mm
Number of hydraulically parallel tubes	10
Number of thermally serial glazings	1
Material of glazing(s)	Tempered glass
Thickness of glazing(s)	3.2 mm

Heat transfer fluid (manufacturers' recommendation)	
Type	Water-Propyleneglycol
Specifications	--

Flow (manufacturers' recommendation)	
Flow range	70 - 310 lh ⁻¹
Rated flow	200 lh ⁻¹

Absorber	
Absorber element	Aluminium sheet
Length of absorber element	2120.0 mm
Width of absorber element	1200.0 mm
Thickness of absorber element	0.40 mm
Coating	Ceramic-metal-structure (Cermet)
Flowed through element	Copper pipe
Joining technique	Laser welded
Joining seam	--

Installation	
On tilted roof	Yes
In tilted roof	No
On flat roof	No
On flat roof with stand	Yes
Facade	No

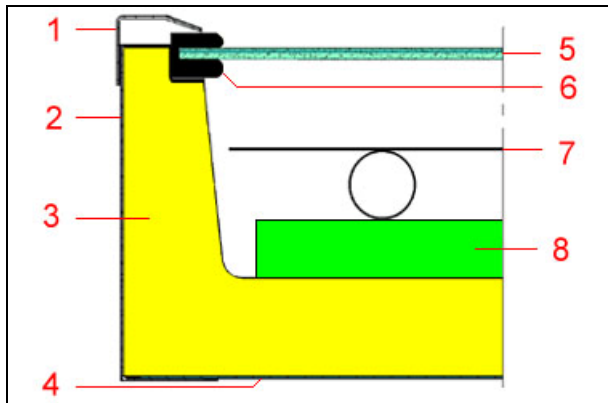
Casing and insulation	
Casing material	Galvanised steel
Sealing material	EPDM
Insulation material	Polyurethane foam, Glass wool
Thickness (in mm)	30, 20
Aperture dimensions	2.130 m * 1.215 m

Limitations (manufacturers' information)	
Max. temperature	140°C
Max. pressure	10 bar
Other	--

Remarks on collector design	
--	

Test schedule	
Test procedures	ISO9806-1:1994, AS/NZS 2535.1:2007
Sample received	08.06.2010
Start of test	11.08.2010
End of test	04.09.2010

1.2 Sketch of Collector



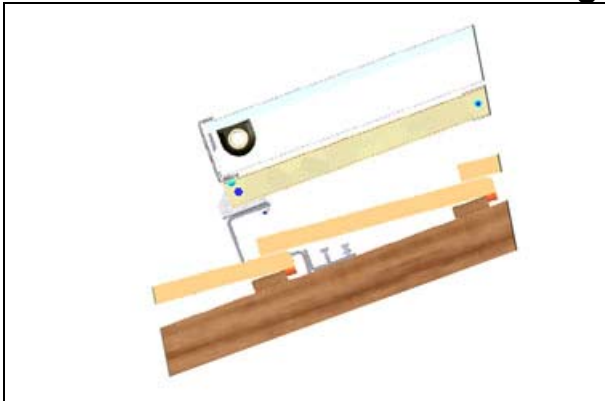
1.3 Specifications on Elements

1	Glass fixing profile Description:	Galvanised steel
2	Frame Type of construction: Material: Profile: Corners: Coating:	Frame Galvanised steel Sheet metal Bent corners Lacquered
3	Thermal insulation Material: Lamination: Thickness [mm]:	Polyurethane foam Aluminium foil 30
4	Rear panel Description: Thickness [mm]:	Polypropylene (PP) 0.5
5	Glazing Material: Thickness [mm]: Properties:	Tempered glass 3.2 Low ferrous content, internally structured
6	Glass fixing profile Description:	EPDM
7	Absorber Absorber element: Flow-through element: Length of element [mm]: Width of element [mm]: Flow type: Joining technique:	Aluminium sheet Copper pipe 2120 1200 Parallel grid Laser welded
7	Absorber coating Tradename: Description: Manufacturing process:	Mirotherm Ceramic-metal-structure (Cermet) Physical vapour deposition (PVD)
8	Thermal insulation Material: Thickness [mm]:	Glass wool 20

1.4 Photo of Collector



1.5 Sketch of Collector Mounting



2 Test Methods and Results

2.1 Test of Thermal Performance

Tests carried out according to ISO 9806-1:1994 and AS/NZS2535.1:2007.

Deviations from this standard are indicated by the formatting identical to this clause. The reasons for the deviations are mentioned.

2.1.1 Schematic of the test loop

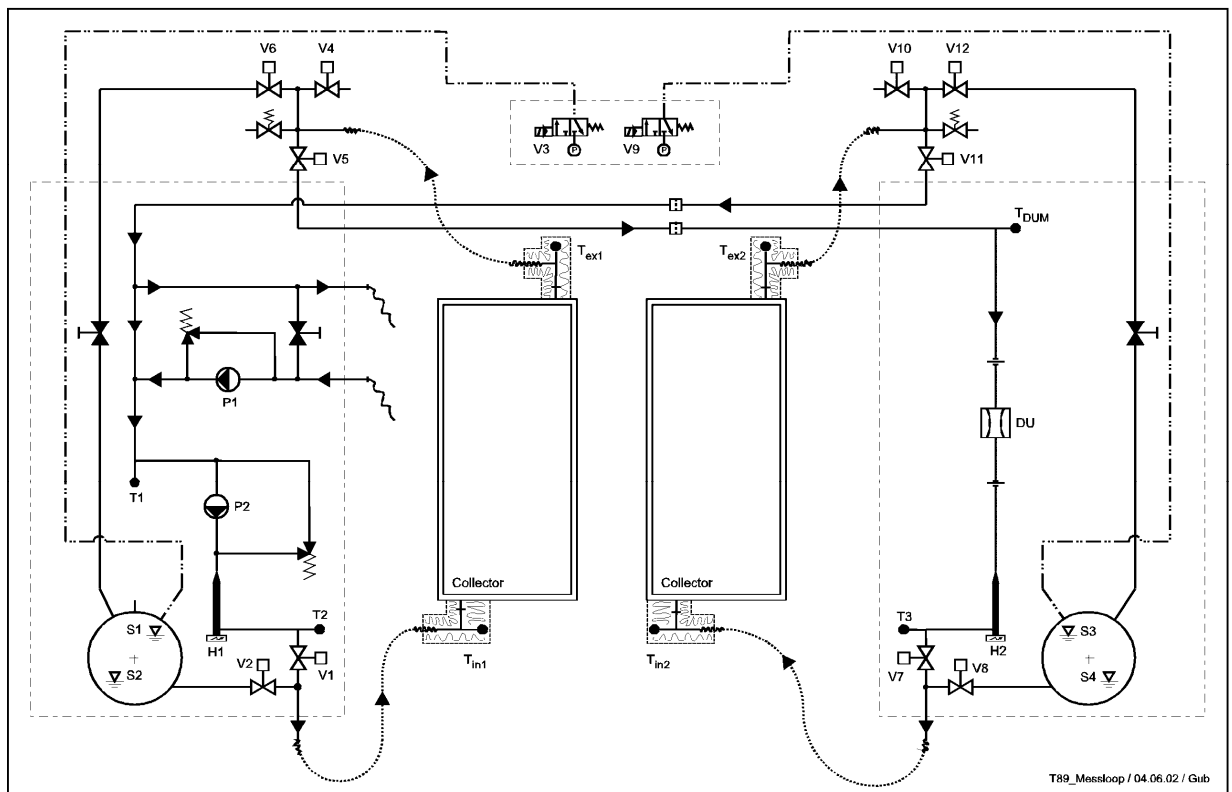


Fig. 2.1: Test loop for efficiency measurements.

2.1.2 Efficiency curve

2.1.2.1 General

Flow rate during test	180.0 l/h
Fluid for tests	33.3 Vol-% ethylene glycol
Test method	stationary (steady state)
Geographical position of test site	47.2°N / 8.8°O, 417 m NN
Collector tilt angle	tracked (45±5)°
Collector azimuth angle	tracked (0±48)°
Definition of efficiency	$\eta = \dot{Q} / A \cdot G$
Thermal output power of collector	\dot{Q}
Reference area	A
Global irradiance	G
Global irradiance on reference area	A · G
Efficiency equation based on T_{in}	$\eta = \eta_0 - a_1 \cdot T_i^* - a_2 \cdot G \cdot T_i^{*2}$
Efficiency equation based on T_m	$\bar{\eta} = \bar{\eta}_0 - \bar{a}_1 \cdot T_m^* - \bar{a}_2 \cdot G \cdot T_m^{*2}$
Temperature at collector inlet	T_{in}
Temperature at collector outlet	T_{ex}
Ambient temperature	T_a
Mean collector temperature	$T_m = (T_{in} + T_{ex}) / 2$
Reduced collector temperature	$T_m^* = (T_m - T_a) / G$ $T_i^* = (T_i - T_a) / G$
Global irradiance for efficiency diagrams	G = 800 W/m ² (where SI units)
Efficiency related to Absorber area	η_{Abs}
Efficiency related to Aperture area	η_{Apt}
Efficiency related to Gross area	η_{Brt}

2.1.2.2 Test results, measured data (SI units)

#	Date / Time [dd.mm.yy hh:mm:ss]	G [Wm ⁻²]	G _d /G [%]	T _a [°C]	u [ms ⁻¹]	T _{in} [°C]	T _{ex} -T _{in} [K]	dV/dt [m ³ s ⁻¹]
1	21.08.10 12:30:00	960.1	19.1	27.53	1.6	111.87	4.77	5.0000E-5
2	21.08.10 12:37:30	961.0	18.7	27.87	1.5	111.87	4.82	5.0000E-5
3	21.08.10 12:59:00	962.3	18.5	28.65	1.8	111.86	4.83	5.0000E-5
4	21.08.10 14:45:30	936.5	17.2	30.08	1.6	58.96	8.10	5.0010E-5
5	21.08.10 15:27:00	890.0	18.7	29.43	1.5	31.25	9.25	5.0000E-5
6	21.08.10 15:34:30	879.4	19.1	29.38	1.6	31.24	9.13	5.0000E-5
7	22.08.10 09:48:30	926.0	13.4	24.09	1.4	53.86	8.21	5.0000E-5
8	22.08.10 09:56:00	934.2	12.9	23.97	1.5	53.86	8.30	5.0000E-5
9	22.08.10 10:39:00	970.8	11.2	25.81	1.3	83.92	6.82	5.0000E-5
10	22.08.10 10:46:30	975.4	11.0	26.12	1.4	83.93	6.89	5.0000E-5
11	22.08.10 10:54:00	975.3	10.9	26.64	1.4	83.93	6.91	5.0000E-5
12	22.08.10 11:01:30	976.2	10.9	26.86	1.3	83.93	6.87	5.0000E-5
13	22.08.10 12:05:30	986.2	12.7	28.74	1.5	111.10	5.17	5.0000E-5
14	22.08.10 12:36:30	982.2	12.7	29.58	1.6	88.89	6.82	5.0010E-5
15	22.08.10 12:44:00	981.3	12.5	29.67	1.5	88.88	6.81	5.0000E-5
16	22.08.10 13:33:00	998.6	11.4	31.41	1.4	59.96	8.74	4.9990E-5
17	22.08.10 13:40:30	1003.9	11.9	31.26	1.4	59.96	8.74	5.0000E-5
18	22.08.10 14:35:30	980.0	10.8	31.12	1.2	32.84	10.12	5.0000E-5
19	22.08.10 14:43:00	973.5	11.0	30.92	1.5	32.84	10.09	5.0000E-5
20	22.08.10 14:50:30	963.0	11.3	30.85	1.7	32.84	10.00	5.0000E-5
21	25.08.10 10:25:30	984.6	12.5	21.08	1.4	21.26	10.34	5.0000E-5
22	25.08.10 11:22:30	996.2	9.3	22.90	1.6	51.93	8.73	5.0000E-5
23	25.08.10 11:30:00	1002.2	9.1	22.71	1.6	51.94	8.76	5.0000E-5
24	26.08.10 11:20:30	983.2	7.3	26.12	1.0	23.39	10.39	5.0000E-5
25	26.08.10 11:28:00	985.9	7.0	26.18	1.1	23.42	10.40	5.0000E-5
26	26.08.10 11:35:30	988.2	6.9	26.78	1.0	23.40	10.44	5.0000E-5
27	26.08.10 11:43:00	990.3	6.8	27.11	1.2	23.39	10.48	4.9990E-5
28	26.08.10 11:50:30	993.6	6.8	26.76	1.4	23.39	10.48	5.0000E-5
29	26.08.10 11:58:00	995.8	6.6	26.91	1.3	23.40	10.51	5.0000E-5
30	26.08.10 14:43:30	970.9	10.4	30.48	1.0	60.77	8.38	5.0000E-5
31	26.08.10 14:51:00	962.6	10.7	29.99	1.2	60.78	8.28	5.0000E-5
32	26.08.10 14:58:30	966.2	10.5	29.97	1.1	60.77	8.37	5.0000E-5

2.1.2.3 Test results, derived data (SI-units)

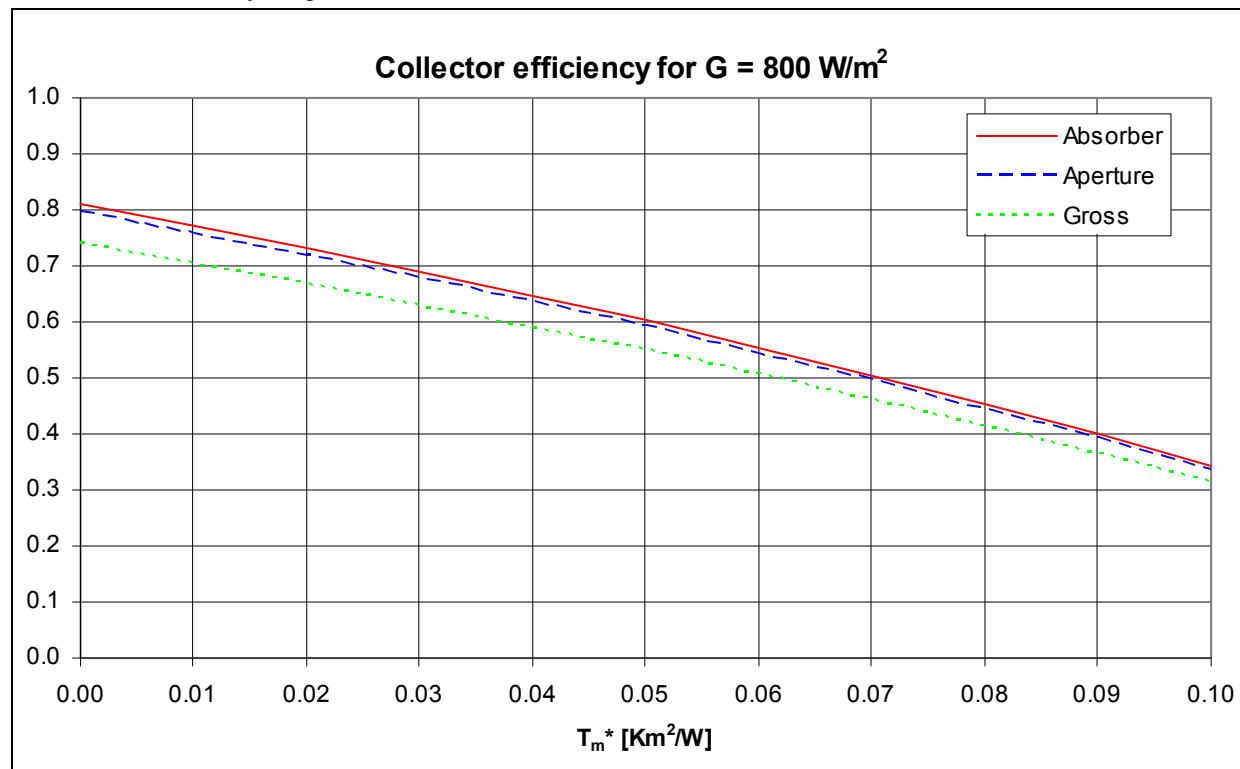
#	T_m [°C]	ρ_{cf} [Jm ⁻³ K ⁻¹]	dQ/dt [W]	T_m^* [m ² KW ⁻¹]	T_i^* [m ² KW ⁻¹]	η_{Abs}	η_{Apt}	η_{Brt}
1	114.26	3876917	923.88	0.090	0.088	0.378	0.372	0.345
2	114.28	3876919	933.72	0.090	0.087	0.382	0.375	0.349
3	114.28	3876920	937.05	0.089	0.086	0.383	0.376	0.350
4	63.01	3870225	1567.99	0.035	0.031	0.658	0.647	0.601
5	35.88	3856751	1784.29	0.007	0.002	0.788	0.775	0.720
6	35.81	3856700	1761.13	0.007	0.002	0.787	0.774	0.719
7	57.96	3868603	1587.31	0.037	0.032	0.674	0.662	0.615
8	58.01	3868622	1605.88	0.036	0.032	0.676	0.664	0.617
9	87.33	3874500	1321.73	0.063	0.060	0.535	0.526	0.489
10	87.38	3874504	1334.51	0.063	0.059	0.538	0.529	0.491
11	87.38	3874505	1338.98	0.062	0.059	0.540	0.530	0.493
12	87.37	3874503	1331.70	0.062	0.058	0.536	0.527	0.490
13	113.69	3876847	1002.45	0.086	0.084	0.400	0.393	0.365
14	92.29	3874943	1320.81	0.064	0.060	0.529	0.520	0.483
15	92.28	3874942	1318.57	0.064	0.060	0.528	0.519	0.482
16	64.33	3870596	1691.72	0.033	0.029	0.666	0.655	0.608
17	64.33	3870596	1691.33	0.033	0.029	0.662	0.651	0.605
18	37.90	3858220	1951.61	0.007	0.002	0.783	0.769	0.715
19	37.88	3858206	1946.77	0.007	0.002	0.786	0.773	0.718
20	37.84	3858176	1928.57	0.007	0.002	0.787	0.774	0.719
21	26.43	3848680	1989.24	0.005	0.000	0.794	0.781	0.725
22	56.30	3867995	1689.02	0.034	0.029	0.666	0.655	0.609
23	56.32	3868003	1693.86	0.034	0.029	0.664	0.653	0.607
24	28.58	3850703	1999.68	0.003	-0.003	0.800	0.786	0.730
25	28.62	3850741	2002.19	0.002	-0.003	0.798	0.785	0.729
26	28.62	3850739	2010.84	0.002	-0.003	0.800	0.786	0.730
27	28.63	3850751	2017.31	0.002	-0.004	0.801	0.787	0.731
28	28.63	3850751	2017.96	0.002	-0.003	0.798	0.785	0.729
29	28.66	3850774	2022.90	0.002	-0.004	0.799	0.785	0.729
30	64.96	3870766	1621.77	0.036	0.031	0.657	0.645	0.600
31	64.92	3870756	1603.16	0.036	0.032	0.655	0.644	0.598
32	64.96	3870765	1619.26	0.036	0.032	0.659	0.648	0.602

2.1.3 Efficiency based on mean temperature of the heat transfer fluid

Data with reference to the absorber area are given in addition to the reference areas required by the standard.

2.1.3.1 Second-order Representation

2.1.3.1.1 Efficiency diagram for $G = 800 \text{ W/m}^2$



2.1.3.1.2 Parameters for efficiency equation:

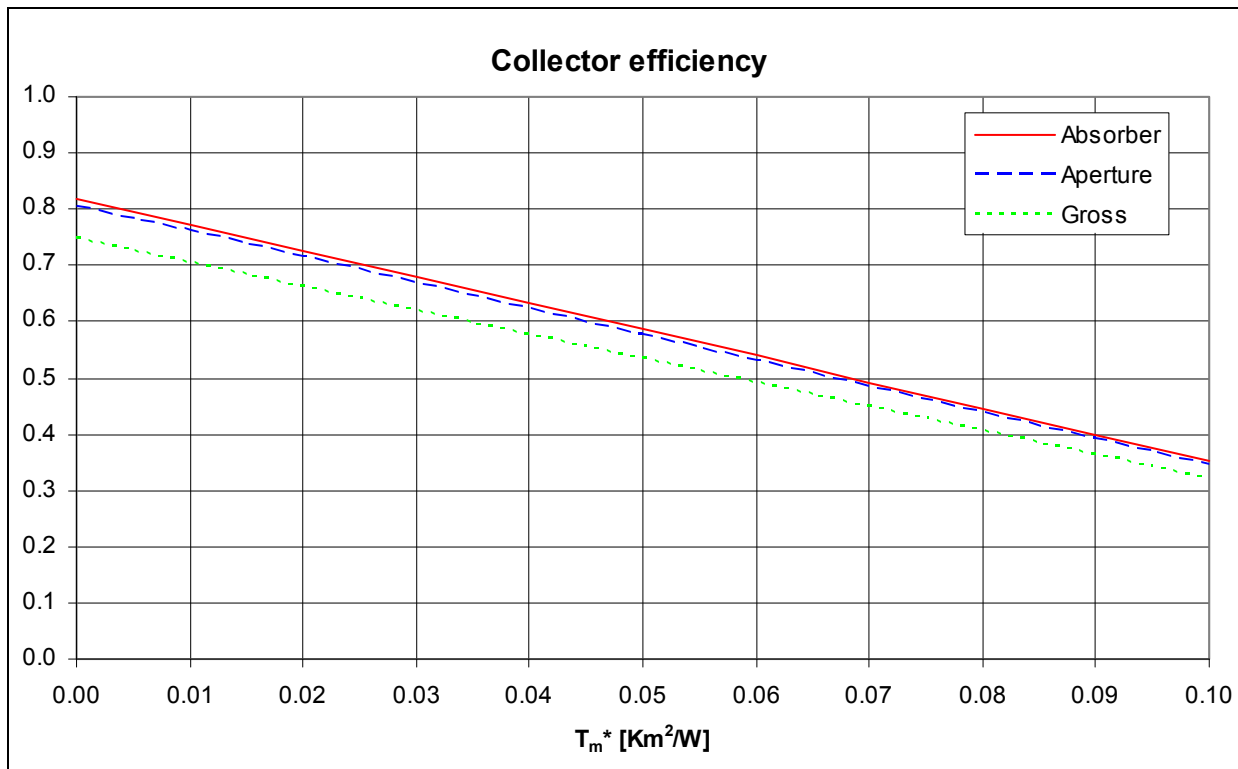
Reference area:	Absorber area	Aperture area	Gross area
$\bar{\eta}_0$ (-)	0.809	0.795	0.738
\bar{a}_1 (W/m²K)	3.62817	3.56803	3.30369
\bar{a}_2 (W/m²K²)	0.01288	0.01268	0.01187

From repetitive measurements of a reference collector, we estimate the following dispersion for the efficiency measurement (standard deviation of the mean, multiplied with a coverage factor 2):

At $T_m^*=0.02$: 0.27 Efficiency-%,
 at $T_m^*=0.05$: 0.44 Efficiency-%,
 at $T_m^*=0.08$: 0.62 Efficiency-%.

2.1.3.2 Linearised representation

2.1.3.2.1 Efficiency diagram



2.1.3.2.2 Parameters for efficiency equation:

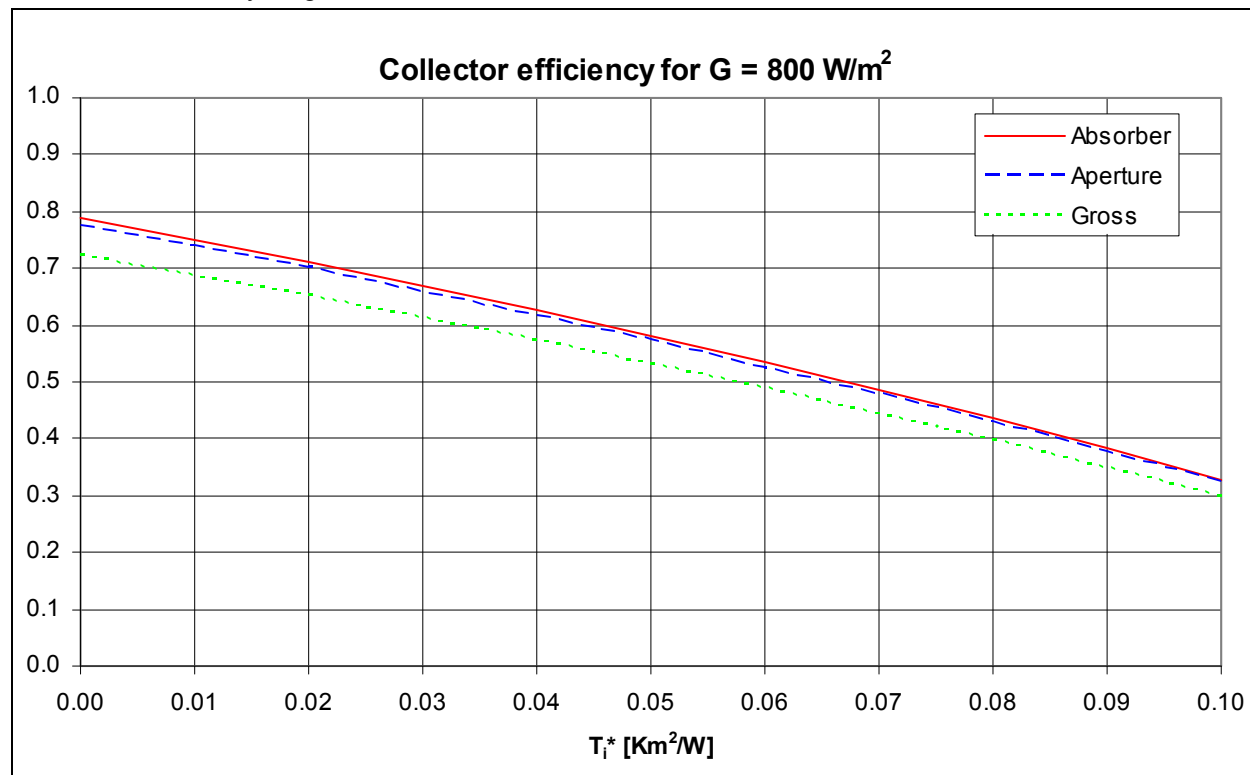
Reference area:	Absorber area	Aperture area	Gross area
$\bar{\eta}_0$ (-)	0.820	0.806	0.748
\bar{a}_1 (W/m^2K^2)	4.68	4.60	4.27

2.1.4 Efficiency based on inlet temperature of the heat transfer fluid

Data with reference to the aperture area are given in addition to the reference areas required by the standard.

2.1.4.1 Second-order Representation

2.1.4.1.1 Efficiency diagram for $G = 800 \text{ W/m}^2$

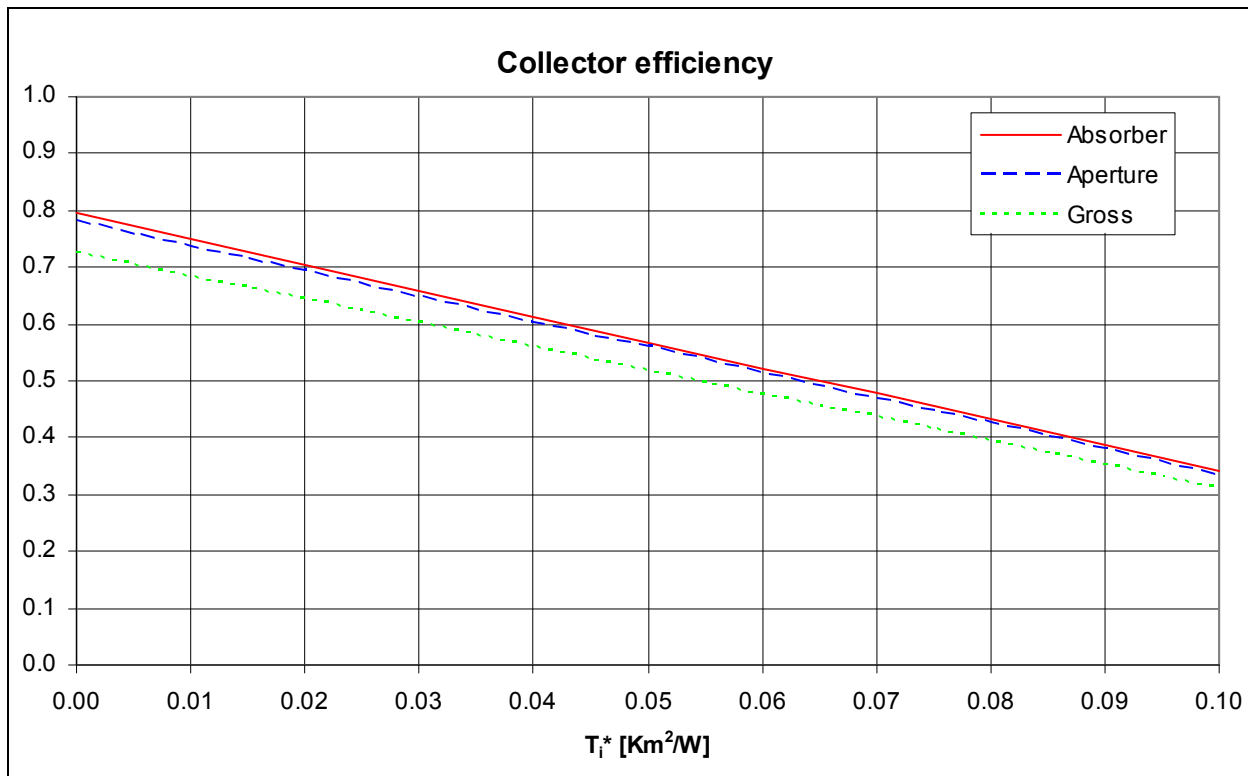


2.1.4.1.2 Parameters for efficiency equation:

Reference area:	Absorber area	Aperture area	Gross area
η_0 (-)	0.789	0.776	0.721
a_1 (W/m ² K)	3.67359	3.61275	3.34647
a_2 (W/m ² K ²)	0.01173	0.01155	0.01081

2.1.4.2 Linearised Representation

2.1.4.2.1 Efficiency diagram

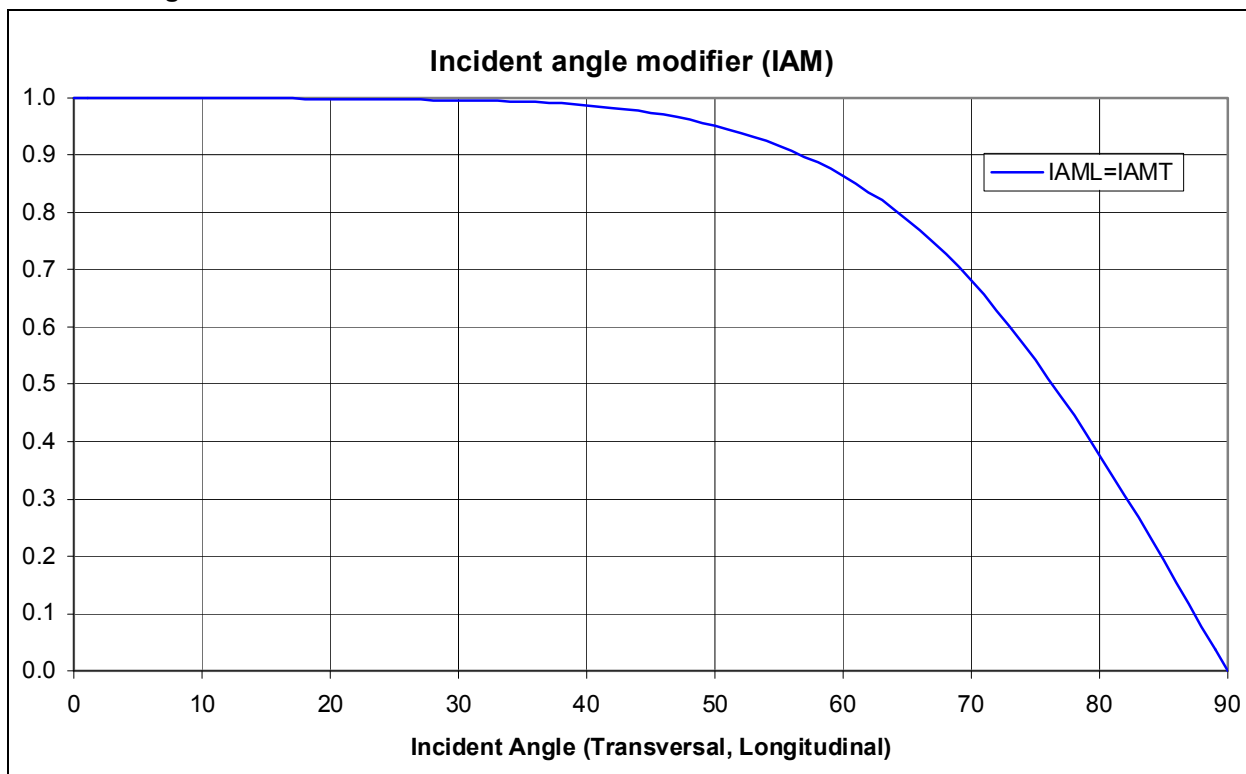


2.1.4.2.2 Parameters for efficiency equation:

Reference area:	Absorber area	Aperture area	Gross area
η_0 (-)	0.795	0.782	0.726
a_1 (W/m ² K ²)	4.54	4.47	4.15

2.2 Incident Angle Modifier (IAM)

2.2.1.1 Diagram



2.2.1.2 Lists of Incidence Angle Modifiers (IAM)

	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
K_{θ} (longitudinal)	1	0.999	0.998	0.995	0.987	0.951	0.863	0.681	0.376	0
K_{θ} (transversal)	1	0.999	0.998	0.995	0.987	0.951	0.863	0.681	0.376	0

	0°	15°	30°	45°	60°	75°	90°
K_{θ} (longitudinal)	1	0.999	0.995	0.974	0.863	0.542	0
K_{θ} (transversal)	1	0.999	0.995	0.974	0.863	0.542	0

2.3 Time Constant

$$\tau_C = 112.0 \text{ s}$$

2.4 Effective Thermal Capacity

2.4.1 Determination according to ISO 9806-1, Annex E, Method E.3

Determination based on transient behaviour of the collector.

$$C_{\text{eff},E3} = 46.2 \text{ kJ/K (Effective heat capacity of collector filled with fluid)}$$

Additional information: The thermal capacity was measured with the properties of „Antifrogen N“. For other fluids, the thermal capacity is calculated as follows:

$$C_{\text{eff},E3} = 4.8 \text{ l} * \text{density} * \text{specific heat capacity of fluid} + 27.2 \text{ kJ/K}$$

2.4.2 Determination according to ISO 9806-1, Section 10.2.

Estimation based on material properties.

$$C_{\text{eff},6162} = 28.8 \text{ kJ/K (Effective heat capacity of collector filled with fluid)}$$

Additional information: The thermal capacity was measured with the properties of „Antifrogen N“. For other fluids, the thermal capacity is calculated as follows:

$$C_{\text{eff},6162} = 4.8 \text{ l} * \text{density} * \text{specific heat capacity of fluid} + 10.3 \text{ kJ/K}$$

2.5 Power Output per Collector Unit

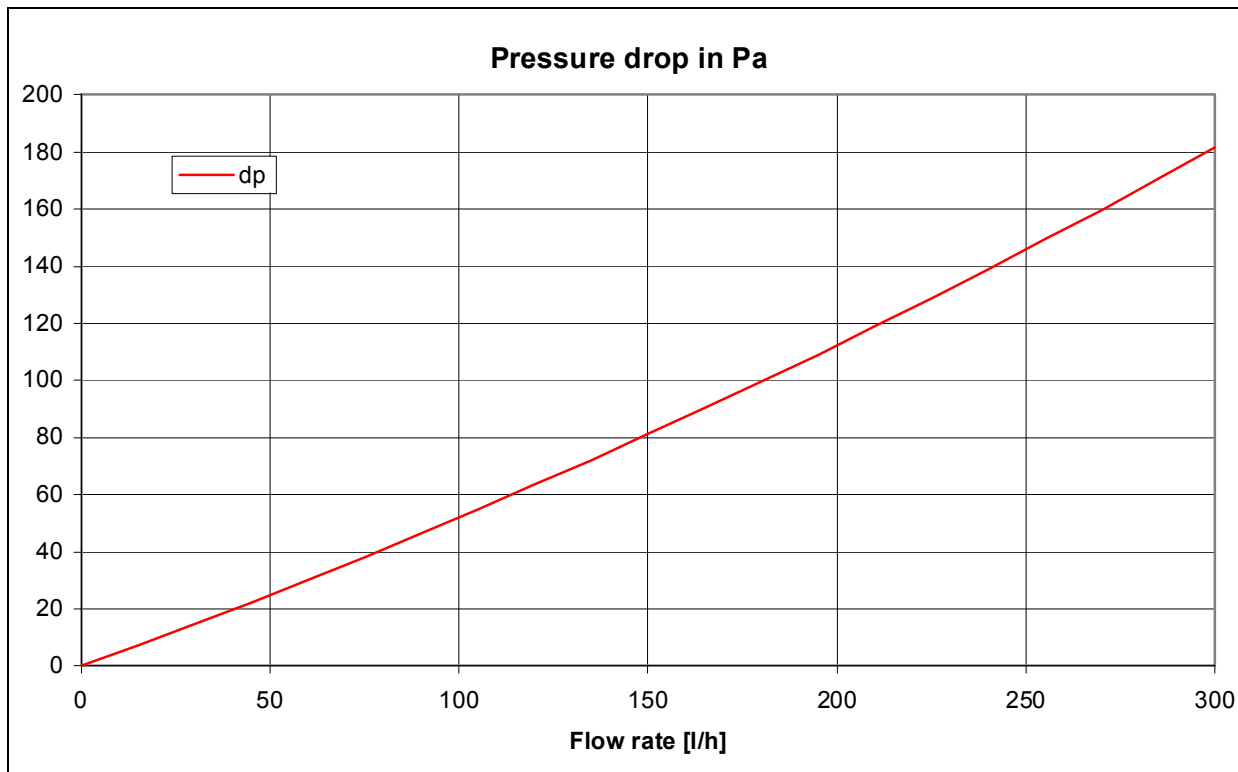
2.5.1 SI-units

$T_m - T_a$	Global irradiance G		
	G=400 W/m ²	G=700 W/m ²	G=1000 W/m ²
10 K	728 W	1345 W	1963 W
30 K	517 W	1134 W	1752 W
50 K	280 W	897 W	1515 W

2.6 Pressure Drop

2.6.1 SI units

2.6.1.1 Diagram



2.6.1.2 Pressure drop at rated flowrate

Conditions:

$T_{\text{fluid}} = 20^{\circ}\text{C}$ and $dV/dt = 200 \text{ l/h}$

$\Delta p = 112 \text{ Pa}$

2.6.1.3 Table of pressure drop data in Pa

Conditions:

$T_{\text{fluid}} = 20^{\circ}\text{C}$

Flowrate [l/h]	50.0	100.0	150.0	200.0	300.0
Pressure drop [Pa]	25.00	52.00	81.00	112.00	182.00

3 Remarks

This report must not be copied except in full.

The test methods applied fulfil the requirements of ISO 9806-1:1994, AS/NZS 2535.1:2007

The test results only refer to the tested collector sample.

This test report is made according to the requirements of ISO 9806-1:1994, AS/NZ S2535.1:2007.

This test report fulfils the requirements of ISO17025.

Rapperswil, 14.12.2010



Dr. Andreas Bohren
Head of SPF Testing



Dipl.-Ing. Walter Gubler
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