

Report of Performance Test according to EN 12975-2 for a Glazed Solar Collector

Test Centre

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Test Basis

Test according to EN 12975-2:2006
Section 6

Test Report

Number 107-06/D
Date 02.11.2006
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Customer

Address Thermomax Ltd.
Balloo Crescent
Bangor, BT 19 7UP
United Kingdom

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Test Collector

Type DF 100 30
Manufacturer Thermomax Ltd.
Serial- or Prototype Serial type
Year of production 2006
Serial number MB 08631

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Test Centre for Solar Thermal
Components and Systems

1. Summary

Company:	Thermomax Ltd. Balloo Crescent Bangor, BT 19 7UP, United Kingdom	Report no.:	107-06/D
		Report date:	02.11.2006
Type:	DF 100 30	Serial no.:	MB 08631
		Year of production:	2006

The following results were obtained from a test of the thermal performance of a solar collector according to **EN 12975-2:2006**. They apply to the collector described more precisely in the test report no. 107-06/D and to the tests and procedures described herein.

Description of the collector

Type	evacuated tubular collector	Aperture area	3.228 m ²
Length/Width/Height	1996 / 2127 / 97 mm	Absorber area	3.020 m ²
Max. operation pressure	8 bar	Gross area	4.245 m ²
Weight, empty	81.4 kg	Recommended flow rate	60..150 kg/m ² h
Heat transfer fluid	polypropylene	Thickness of absorber sheet	0.12 mm
		number of tubes	30

Test results

Coefficients of efficiency

(determined outdoor)

$$\eta = \eta_0 - a_1 \cdot (t_m - t_a) / G - a_2 \cdot (t_m - t_a)^2 / G$$

Based on: aperture area absorber area

$\eta_0 =$	0.779	0.832
$a_1 =$	1.07 W/m ² K	1.14 W/m ² K
$a_2 =$	0.0135 W/m ² K ²	0.0144 W/m ² K ²

Incident angle modifier

(determined outdoor)

proj. angle of incidence θ	0°	10°	20°	30°	40°	50°	60°
$K_{\theta b, trans}(\theta_{trans})$	1.00	1.01	1.04	1.07	1.07	1.02	0.90
$K_{\theta b, long}(\theta_{long})$	1.00	1.00	0.99	0.98	0.96	0.92	0.86
$K_{\theta d} =$	0.90						

Power output per collector unit

$T_m - T_a$	Irradiance	
	400 W/m ²	700 W/m ² 1000 W/m ²
10 K	967	1721 2475
30 K	863	1617 2371
50 K	724	1478 2233

Peak power per collector unit **2514 W_{peak}** at $G = 1000 \text{ W/m}^2$ and $t_m - t_a = 0 \text{ K}$

Pressure drop (water, 20 °C) $\Delta p = 1.2 \text{ mbar}$ at $\dot{m} = 70.5 \text{ kg/h}$
 $\Delta p = 5.9 \text{ mbar}$ at $\dot{m} = 210.4 \text{ kg/h}$

Thermal capacity (calculated) $c = 9.2 \text{ kJ/(m}^2\text{K)}$ $C = 29.6 \text{ kJ/K}$

Stagnation temperature $t_{stg} = 286 \text{ °C}$ at $G_S = 1000 \text{ W/m}^2$ and $t_{as} = 30 \text{ °C}$

Emmerthal, 02.11.2006

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Dipl.-Ing. C. Lampe, deputy head of Test Centre-EN

2. Description of the Collector

2.1. Collector

Manufacturer	Thermomax Ltd. Balloo Crescent; Bangor, BT 19 7UP;United Kingdom
Type	DF 100 30
Construction	evacuated tubular collector, Serial type
Year of production	2006
Serial number	MB 08631
Weight, empty, without glazing	41.7 kg (according to manufacturer)
Weight, empty, with glazing	81.4 kg (weighed at ISFH)

2.2. Evacuated Tubes

Number of tubes	30
Dimensions	65 mm / 1.5 mm (outer diameter/ thickness)
Material	borosilicate glass, clear
Aperture area	30 x 1735.7 mm x 62 mm = 3.228 m ²

2.3. Absorber

Absorber material	copper sheet, thickness 0.12 mm (according to manufacturer)
Material of fluid tubes	copper
Connection between absorber and tubes	inductive welding
Hydraulic construction	parallel
Absorber layer	selective (TiNOX, type TiNOX)
Absorber dimensions	30 x 1706.5 mm x 59 mm = 3.020 m ² (according to manufacturer)

2.4. Heat Transfer Fluid

Specifications	polypropylene
Alternative acceptable heat transfer fluids	no details
Fluid content	5.6 l (weighed at ISFH)

2.5. Casing

Dimensions (L / W / H)	1996 / 2127 / 97 mm
Material of frame	aluminium profiles

2.6. Insulation in the Distributor Casing

Insulation construction	machine-cut foamed plastic
Insulation material	foamed melamine resin

2.7. Reference Areas

Absorber area	3.020 m ²
Aperture area	3.228 m ²
Gross area	4.245 m ²

2.8. Collector Mounting

Collector tilt angle	0°..90°
On sloped roof	yes
Integrated into sloped roof	no
On flat roof	yes
On flat roof with stand	yes
Facade	yes

3. Validity

1. This test report is valid for the collector DF 100 30 (description see section 2) with the serial number MB 08631.
2. According to the customers specifications the collector type DF 100 30 is distributed with the selective absorber layer type TiNOX (TiNOX) and type Sunselect (Alanod-Sunselect). In an agreement of the Erfahrungsaustauschkreis „Thermische Solaranlagen und deren Bauteile“(EK-TSuB) which consists of representatives from all German-speaking test centres acknowledged by DIN CERTCO (Certification body of DIN) the test results of this two absorber layers are transferable (confirmed 21.03.2006). Therefore the report no. 107-06/D is also valid for the collector type DF 100 30 with the selective absorber layer type Sunselect (Alanod-Sunselect).

4. Photograph and Sketch of the Collector



Fig. 4-1: Picture of the collector, mounted in the sun simulator SUSI I



Fig. 4-2: Sketch of the collector

5. Sampling

Date of sampling:	29.03.2006
Place of sampling:	Store of the company Thermomax Ltd.; Bangor, BT 19 7UP; United Kingdom
Inspector:	Daniel Eggert (employee of the Test Centre)
Description of sampling:	<p>The collector casing with the serial number MB 08631 and the evacuated tubes with the serial number C063LT00029, C063LT00031 and C063LT00032 were chosen out of more than 6 identically products. The products were marked in the store and delivered to the test centre. The customer has proved with his quality management that the chosen products accord with the serial production.</p>

6. Documents; Collector Identification

Drawings:	<p>The following drawings were presented by the customer</p> <ul style="list-style-type: none"> * sketch of the collector * Top view * Lateral view
Collector data sheet:	A data sheet with details about the tested collector was presented by the customer.
Labelling of the collector:	The test collector has a durable type label. The label is fixed inside the manifold lid to avoid early destruction. The manifold can be opened without any tool. The stagnation temperature isn't printed on the label, because the determination will be carried out with this report.
Installer instruction manual:	<p>The following documents were presented by the customer:</p> <p>Installation manual (2006 B4815A)</p> <p>Operatung manual (2006 B4986A)</p>

7. Installation of Sensors

The collector was equipped with temperature sensors (Pt 100, class A), as described in the following. Care was taken that the sensors do not influence the results of the following tests.

Name of the sensor	Position
t_{sm}	Absorber temperature sensor, at 2/3 of the height of the absorber tube, inside the 10th fluid tube (installed only during the exposure to irradiation)
t_{glass}	Glass temperature sensor, at 2/3 of the height of the glass tube (10th tube from the left side)
t_{back}	Backside temperature sensor (exactly beneath glass temperature sensor)

8. Exposure to Irradiation

The empty collector was exposed to irradiation before the performance test.

Tab. 8-1: Test conditions during the exposure

Date:	26.04.2006 to 03.05.2006	
Test facility:	Tracker (outdoor test)	
Inspector:	Florian Kohlenberg (employee of the Test Centre)	
	Conditions stipulated in EN 12975-2	Test conditions
Collector tilt angle	-	45 °
Solar irradiance	> 700 W/m ²	ca. 984 W/m ²
Ambient temperature, mean value	-	ca. 20.5 °C
Duration of exposure	> 5 h	5 h
Result:		
The collector showed no changes during and after the exposure test.		

9. Determination of the Stagnation Temperature

The determination of the stagnation temperature is carried out in the report 32-06/D with the collector type Solar Plus DF 20. The results are also valid for the collector type DF 100 30, because the difference between those collector types is only the number of tubes and has got no influence on the stagnation temperature.

During the exposure to irradiation (see section 8), the stagnation temperature of the collector was determined.

9.1. Mathematical Procedure^a

$$t_{\text{stg}} = a \cdot G_s^{\frac{1}{1.3}} + t_{\text{as}} \quad \text{eqn. (9.1)}$$

t_{stg} = stagnation temperature under standard conditions in °C

G_s = standard global irradiance

t_{as} = standard ambient temperature

$$a = \frac{(t_{\text{sm}} - t_{\text{am}})}{G_m^{1/1.3}} \quad \text{eqn. (9.2)}$$

t_{sm} = measured absorber temperature in °C

t_{am} = measured ambient temperature in °C

G_m = measured global irradiance (in the collector plane) in W/m²

9.2. Test Conditions and Results

Date:	05.04.2006		
Test facility:	SUSI I (indoor test with sun simulator)		
Inspector:	Gerd Schiewe (employee of the Test Centre)		
Collector tilt angle:	45°		
	Test conditions	Standard conditions according to ISO 9806-2	
		Class A (temperate), corresponding to conditions stipulated in EN 12975-2	Class B (sunny)
Global irradiance	895 W/m ²	1000 W/m ²	1100 W/m ²
Surrounding air speed	< 1 m/s	< 1 m/s	< 1 m/s
Ambient temperature	30.1 °C	30 °C	40 °C
Measured absorber temperature (t_{sm})	264.9 °C		
Calculated stagnation temperature (t_{stg})		286 °C	315 °C

a. For the calculation of the stagnation temperature under standard conditions, the eqns. (9.1) and (9.2) are used, as this method has a lower uncertainty than the procedure described in EN 12975-2.

10. Instantaneous Collector Efficiency

10.1. Test Procedure

Outdoor thermal performance testing under steady state conditions (see EN 12975-2, section 6.1.4).

10.2. Mathematical Description

$$\eta = \eta_0 - a_1 \cdot \frac{t_m - t_a}{G} - a_2 \cdot \frac{(t_m - t_a)^2}{G} \quad \text{eqn. (10.1)}$$

η = efficiency

η_0 = efficiency for $t_m - t_a = 0$ (conversion factor)

a_1 = heat loss coefficient, independent of temperature, in $\text{W/m}^2\text{K}$

a_2 = heat loss coefficient, depending on temperature, in $\text{W/m}^2\text{K}^2$

G = global irradiance in W/m^2

t_m = mean fluid temperature in the collector in $^{\circ}\text{C}$, $t_m = (t_{in} + t_e)/2$

t_{in} = collector inlet temperature in $^{\circ}\text{C}$

t_e = collector outlet temperature in $^{\circ}\text{C}$

t_a = ambient temperature in $^{\circ}\text{C}$

T_m^* = reduced temperature difference, in $\text{m}^2\text{K/W}$

10.3. Test Conditions and Results

The test conditions are shown in table 10-1. All measured data are given in table A-1 in the appendix.

Tab. 10-1: Test conditions of the efficiency measurements

Date:	03.05.2006 and 05.05.2006	
Test facility:	Tracker (outdoor)	
Inspector:	Florian Kohlenberg (employee of the Test Centre)	
Heat transfer fluid:	water	
	Conditions stipulated in EN 12975-2	Test conditions
Collector tilt angle	40...50°	45°
Mean global irradiance	> 700 W/m ²	985.0 W/m ²
Mean ambient temperature	-	22.3 °C
Mean air speed over the collector	3 m/s ± 1 m/s	2 m/s
Mass flow rate of the heat transfer fluid	0.02 kg/(m ² s) or according to manufacturer	225 kg/h

Tab. 10-2: Coefficients of the efficiency curve, related to different areas

Related to area:	η_0	a_1	a_2
Aperture area (3.228 m²)	0.779	1.07 W/m²K	0.0135 W/m²K²
Absorber area (3.020 m ²)	0.832	1.14 W/m ² K	0.0144 W/m ² K ²
Gross area (4.245 m ²)	0.592	0.81 W/m ² K	0.0102 W/m ² K ²

Note:

If the parameters are given in the documents of the collector, the area to which they are related must be mentioned.

The power curve per collector unit for $G = 1000 \text{ W/m}^2$ is given on page 18.

11. Incident Angle Modifier of the Collector

11.1. Test Procedure

The collector is mounted on the outdoor test facility (Tracker), facing south in a fixed position. The variation of the incident angle is achieved by the sun's path over the collector. The vacuum tube collector on hand shows a biaxial incident angle dependence. So, after determination of the transversal incident angle modifier the collector is turned by 90°, and the longitudinal incident angle modifier is determined in a second measurement. The incident angle modifiers for direct radiation and for diffuse radiation are determined separately.

11.2. Mathematical Description

$$K_{\theta b}(\theta) = \frac{F'(\tau\alpha)_{en}(\theta)}{F'(\tau\alpha)_{en}} \quad \text{eqn. (11.1)}$$

$K_{\theta b}(\theta)$ = incident angle modifier for beam radiation as a function of the incident angle θ

$F'(\tau\alpha)_{en}$ = conversion factor for pure beam radiation at normal incidence

$F'(\tau\alpha)_{en}(\theta)$ = conversion factor for pure beam radiation as a function of the incident angle θ

The incident angle modifier for beam radiation must be split into a transversal and a longitudinal component:

$$K_{\theta b}(\theta) = K_{\theta b, trans}(\theta_{trans}) \cdot K_{\theta b, long}(\theta_{long}) \quad \text{eqn. (11.2)}$$

θ_{trans} = transversal incident angle

θ_{long} = longitudinal incident angle

11.3. Test Conditions and Results

Tab. 11-1: Test conditions during the measurement of the incident angle modifier

Date:	06.05.2006 to 12.05.2006	
Test facility:	Tracker (outdoor)	
Inspector:	Florian Kohlenberg (Mitarbeiter des Prüfzentrums)	
Heat transfer fluid:	water	
	Conditions stipulated in EN 12975-2	Test conditions
Collector tilt angle	40...50°	34.5° ¹⁾
Collector azimuth angle	-	0° (south)
Mass flow rate \dot{m}	0.02 kg/(m ² s) or according to manufacturer	223 kg/h
Latitude	-	52.1° N
Longitude	-	9.4° E
Local time (MEZ) at solar noon	-	12:20

1) This tilt angle was selected in order to achieve the best approximation of normal irradiance. The tilt angle is only insignificantly below the smallest demanded value. The influence of the tilt angle on the collector performance is assessed to be minimal in this range of angles.

Tab. 11-2: Incident angle modifier

θ_{trans} or θ_{long}	0°	10°	20°	30°	40°	50°	60°
$K_{\theta b, \text{trans}}(\theta_{\text{trans}})$	1.00	1.01	1.04	1.07	1.07	1.02	0.90
$K_{\theta b, \text{long}}(\theta_{\text{long}})$	1.00	1.00	0.99	0.98	0.96	0.92	0.86
$K_{\theta d}$	0.90						

Nomenclature

θ_{trans} = transversal incident angle

θ_{long} = longitudinal incident angle

$K_{\theta b}(\theta)$ = incident angle modifier for beam radiation as a function of the incident angle θ

$K_{\theta d}$ = incident angle modifier for diffuse radiation

12. Thermal Capacity of the Collector

The thermal capacity of the collector is calculated according to EN 12975-2, as the sum of the capacities of its constituent elements, taking into account weighting factors. These weighting factors evaluate that some elements are only partially involved in the thermal inertia of the collector.

$$C = \sum p_i \cdot m_i \cdot c_i \quad \text{eqn. (12.1)}$$

C = effective thermal capacity of the collector in kJ/K

p_i = weighting factor of the component (according to tabular 6 in EN 12975-2:2001, chapter 6.1.6.2)

m_i = Mass of the component in kg

c_i = specific thermal capacity of the component kJ/(kgK)

12.1. Result

Date:	20.07.2006
Inspector:	Wolfgang Wetzel
	calculated according to EN 12975-2
effective thermal capacity	29.6 kJ/K
specific thermal capacity related to the aperture area	9.2 kJ/(m ² K)

13. Pressure Drop across the Collector

13.1. Test Procedure

The pressure drop is measured at different mass flow rates according to EN 12975-2, chapter 6.1.8.

13.2. Test Conditions and Results

Tab. 13-1: Results of the pressure drop measurements

Date:	26.06.2006				
Test facility:	Δp -test facility with U-tube differential pressure gauge				
Inspector:	Gerd Schiewe (employee of the Test Centre)				
Heat transfer Fluid:	water				
Fluid temperature:	$20 \pm 2^\circ\text{C}$				
Mass flow rate in kg/h	29.5	70.5	129.6	210.4	299.8
Pressure drop in mbar	0.4	1.2	2.8	5.9	10.4

Compared to the measurement using water, the pressure drop will be markedly higher when using a water-glycol mixture as heat transfer fluid, because its viscosity is much higher.

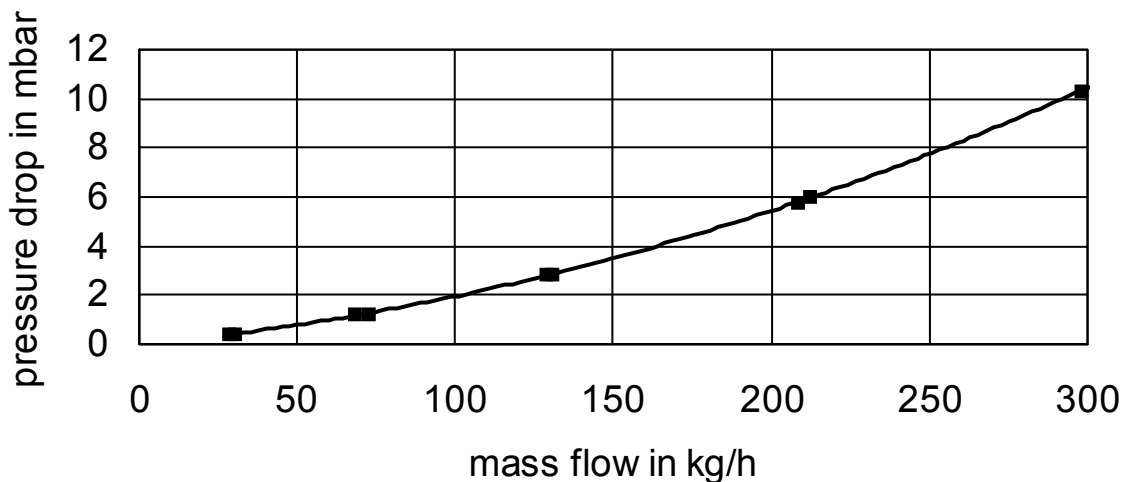


Fig. 13-1: Measured pressure drop of the collector (heat transfer fluid: water)

14. Observations; Status of the Collector

Status of the collector after

- * delivery: faultless
- * exposure to irradiation: no change
- * performance test: no change
- * end of tests: no change

There were no extraordinary incidents during the tests.

No sharp edges, loose fixing elements or other characteristics representing a possible endangering were observed.

15. Stipulations from the Test Centre

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Test Centre for Solar Thermal

Components and Systems

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deputy head of Test Centre-EN

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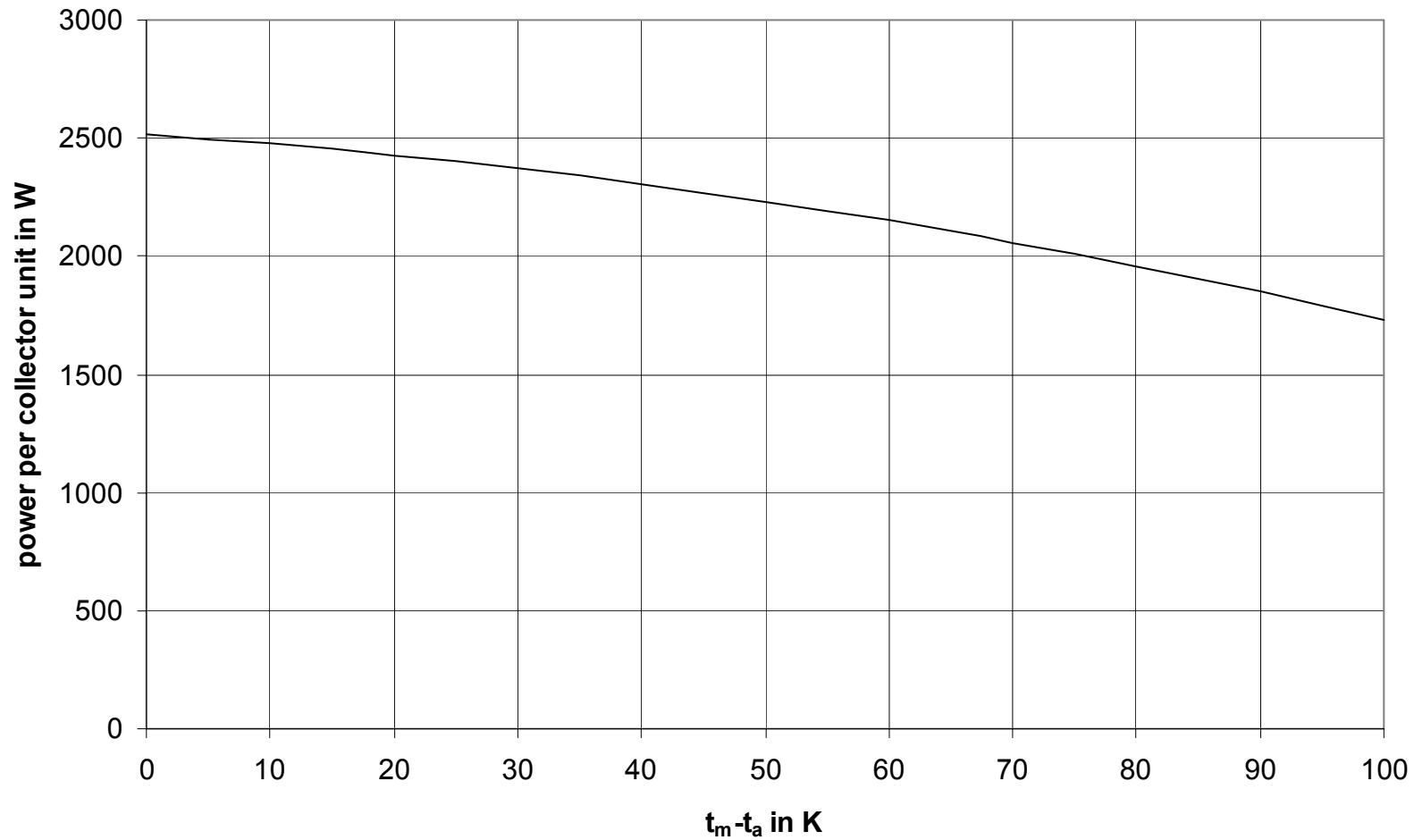
Table A-1: Measured and Calculated Data from the Efficiency Tests, Related to the Aperture Area

No.	G	\dot{m}	t_{in}	t_e	$t_e - t_{in}$	t_m	t_a	$t_m - t_a$	T^*_m	η_a
-	W/m ²	kg/h	°C	°C	K	°C	°C	K	Km ² /W	-
1	949.4	221.5	39.6	48.5	8.9	44.0	23.4	20.6	0.0217	0.749
2	940.1	221.9	39.5	48.4	8.8	44.0	23.2	20.7	0.0220	0.749
3	927.2	222.6	39.5	48.2	8.7	43.9	23.2	20.7	0.0223	0.748
4	923.8	223.1	39.5	48.1	8.5	43.8	23.1	20.7	0.0224	0.742
5	1016.3	221.1	76.5	85.0	8.6	80.7	23.1	57.6	0.0567	0.674
6	1039.2	226.5	77.1	85.6	8.5	81.4	21.5	59.9	0.0576	0.672
7	1041.5	226.2	77.2	85.7	8.6	81.5	21.5	59.9	0.0575	0.671
8	1036.3	226.2	77.2	85.7	8.5	81.5	22.0	59.5	0.0574	0.671
9	983.2	222.5	58.6	67.0	8.4	62.8	24.0	38.8	0.0395	0.687
10	972.5	225.4	58.5	67.1	8.6	62.8	24.0	38.9	0.0400	0.718
11	891.0	228.1	58.5	66.2	7.7	62.4	23.6	38.8	0.0435	0.706
12	917.8	228.1	58.5	66.3	7.8	62.4	23.7	38.7	0.0422	0.698
13	1005.4	232.7	18.6	28.1	9.5	23.3	25.0	-1.7	-0.0017	0.788
14	1010.8	232.7	18.6	28.1	9.5	23.3	25.2	-1.9	-0.0018	0.783
15	1014.1	223.1	15.4	25.1	9.7	20.3	18.5	1.7	0.0017	0.770
16	1019.3	223.1	15.4	25.2	9.8	20.3	18.7	1.6	0.0016	0.770

Nomenclature:

G	W/m ²	hemispherical (= global) solar irradiance in the collector plane
\dot{m}	kg/h	mass flow rate of the heat transfer fluid
t_{in}, t_e	°C	collector inlet temperature and collector outlet (exit) temperature
t_m	°C	mean temperature of heat transfer fluid, $t_m = (t_{in} + t_e)/2$
t_a	°C	ambient temperature
T^*_m	(m ² K)/W	reduced temperature difference, $T^*_m = (t_m - t_a)/G$
η_a	-	collector thermal efficiency, related to the aperture area

Power Curve for $G = 1000 \text{ W/m}^2$, Related to Collector Unit



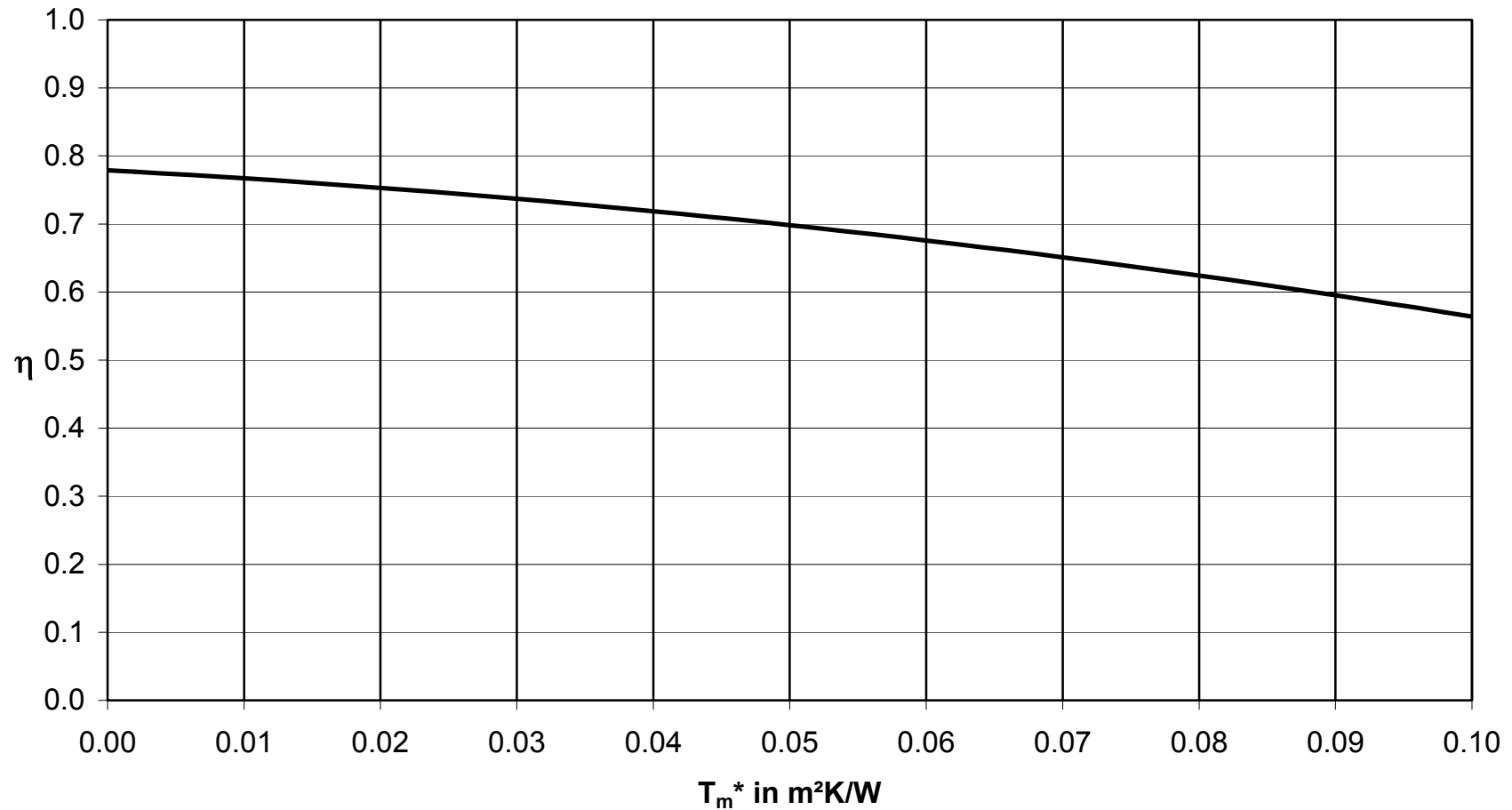
Company: Thermomax Ltd.
Collector type: DF 100 30
Serial No.: MB 08631
Aperture area: 3.228 m²

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Collector Efficiency Curve for $G = 800 \text{ W/m}^2$, Related to the Aperture Area



Company: Thermomax Ltd.
Collector type: DF 100 30
Serial No.: MB 08631
Aperture area: 3.228 m^2

Solar collector test
according to EN 12975-2



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