

Sezione: ENE-BIO

"Laboratorio di Qualificazione Collettori e Sistemi Solari"
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Test report according to EN 12975-2:2001
Solar collector:
MERLONI TERMOSANITARI – Mod. TOP

Collector reference N°: 76d

Collector received in date: 31.05.2005

Manufacturer:

Merloni TermoSanitari SpA
Viale Aristide Merloni n° 45 – 60044 – Fabriano (AN)
Tel: 0732-6011 Fax: 0732-602200

Date: January 13th, 2006


Responsible of testing:

Dr. Vincenzo Sabatelli



Head of Test Laboratory:

Eng. Giacobbe Braccio



ENEA
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SEZIONE BIO
LABORATORIO SOLARE TERMICO
IL RESPONSABILE
Ing. Giacobbe Braccio

Test Report

Collector reference N°:	76d
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Test laboratory:	ENEA - Centro Ricerche Trisaia		
	Sezione: ENE-BIO		
Address:	S.S. 106 Jonica km 419.500 - 75026 Rotondella (MT)		
Date:	13/01/2006	Tel:	+39-0835-974387 +39-0835-974325
		Fax:	+39-0835-974210

A.1 Description of the collector

A.1.1 Manufacturer: **MERLONI TERMOSANTARI**
Brand name: **TOP**
Serial n°: **3205**

A.1.2 Collector:
 Type: *Flat-plate*
 Material of the casing: Alluminium
 Weight empty: 38 kg
 Dimensions: 1000 x 2000 x 10 mm
 Total area: **2,00** m²
 Aperture area: **1,83** m²
 Absorber area (evaluated according to EN 12975:2001): 1,76 m²
 Cover:
 N° of covers: 1
 Material: Prismatic antireflective solar glass
 Thickness: 4 mm
 Channels:
 Number of channels: 8
 Diameter: 10 mm
 Thickness: 0,5 mm

A.1.3 Heat transfer fluid:
 Type: Glycol - HELIOTERM
 Specifications: Atoxic, anticorrosive
 Alternative acceptable heat transfer f: Propilenic glycol

A.1.4 Absorber:
 Material: Copper
 Surface treatment: Selective coating "TINOX"
 Costruction type: Continuum welding
 Fluid content: 1,5 litres
 Weight empty: - kg
 Dimensions: 1910 x 920 m²

A.1.5 Thermal insulation:
 Insulation material: Glass wool + Rock wool
 Thickness of the insulation: - mm



N° riferimento collettore:	76d
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A.1.6 Limitations:

Maximum operation temperature:

99 °C

Maximum operation pressure:

6 bar

Altro: *****

A.1.7 Test method:

Standard EN 12975-2:2001

A.1.8 Annotations:

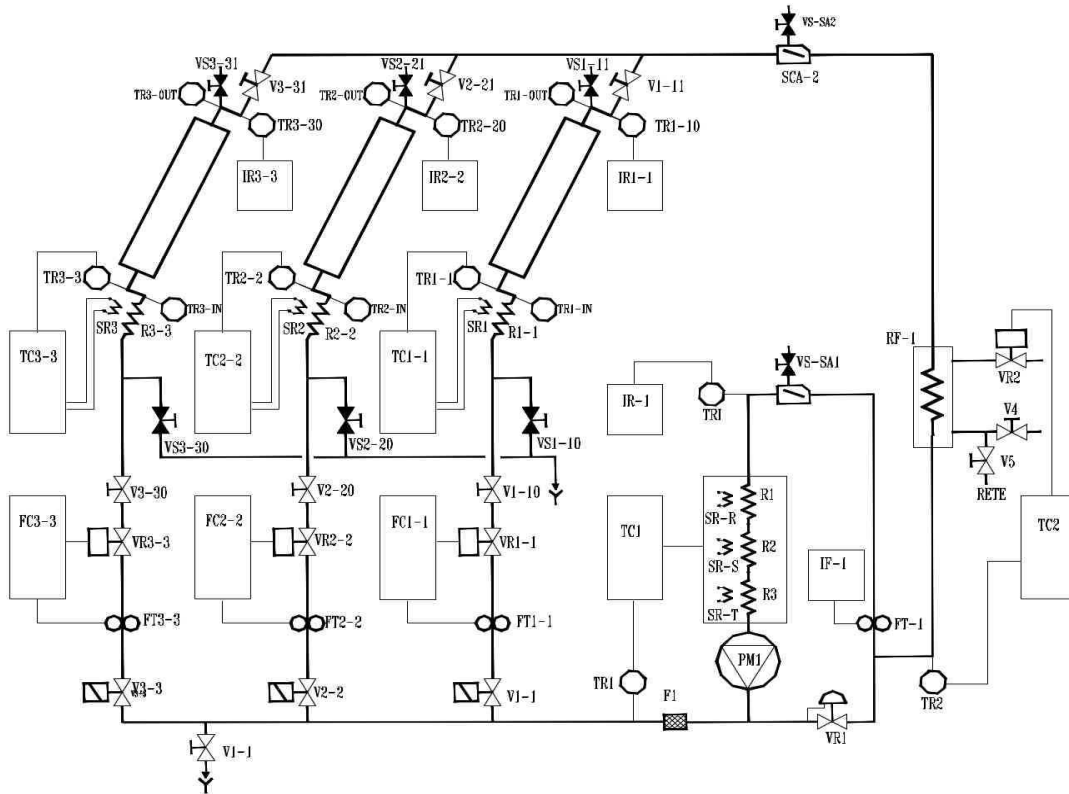
Collector reference N°:	76d
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A.2 Thermal performance test

A.2.1 Method

X	Outdoor , in steady-state condition
	Indoor , in steady-state condition

A.2.2 Schematic diagram of collector mounting



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A.2.4 Istanteneus efficiency curve based on absorber area

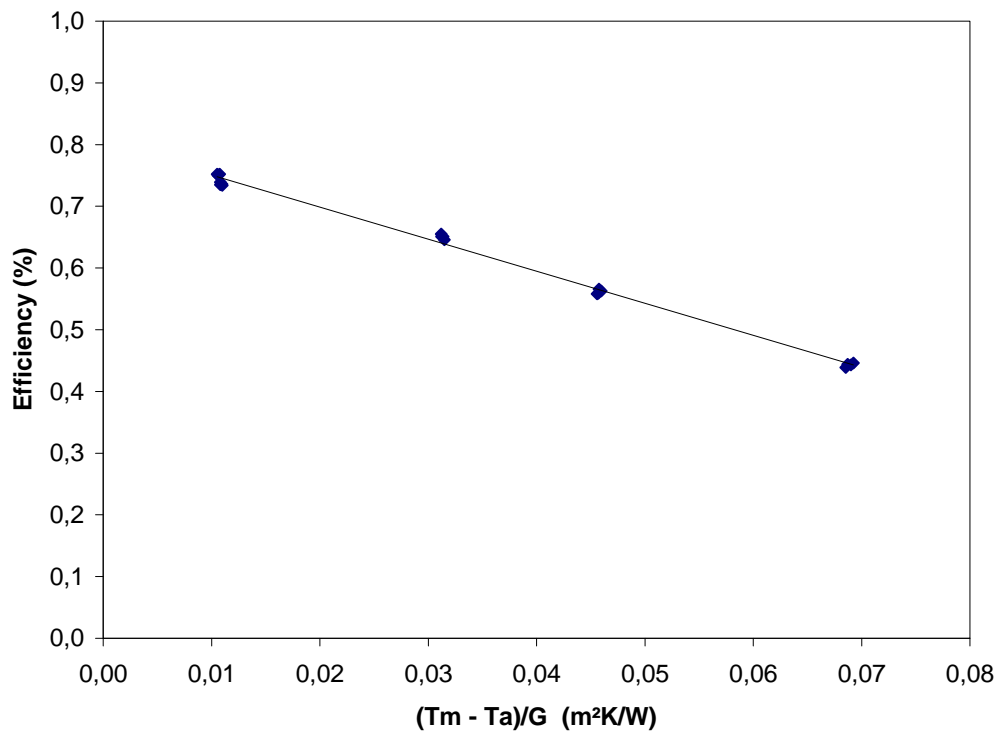
A.2.4.1 Linear fit

Istanteneus efficiency defined as: $\eta = \frac{Q}{AG}$

Total collector area: 2,00 m²

Mean flow rate: 0,04 kg/s

Absorber area: 1,76 m²



Linear regression curve: $\eta = \eta_0 + U_c \frac{T_m - T_a}{G}$

$\eta_0 = 0,803$

$U_c = -5,2 \text{ W/m}^2\text{K}$

Efficiency corresponding to some values of $T^* = (T_m - T_a)/G$:

	$T^* = 0,02$	$T^* = 0,0375$	$T^* = 0,05$
$\eta =$	0,699	0,608	0,543

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A.2.4.2 Second order fit

Istanteneus efficiency defined as: $\eta = \frac{Q}{AG}$

Total collector area:

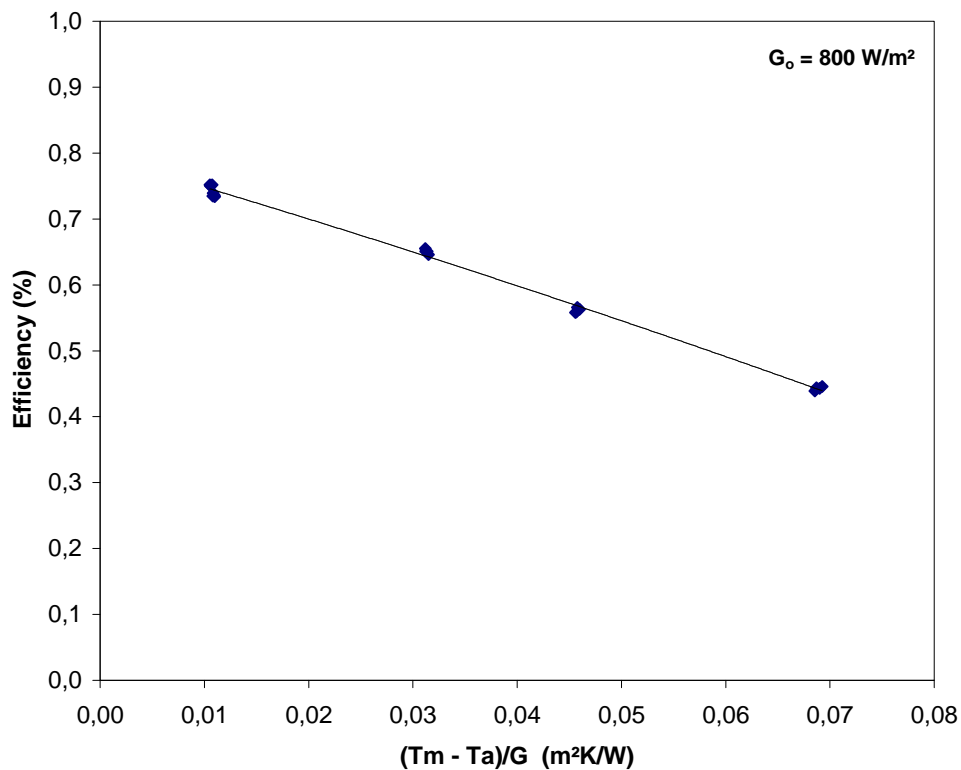
2,00 m²

Mean flow rate:

0,04 kg/s

Absorber area:

1,76 m²



Second order curve: $\eta = \eta_0 + a_1 \frac{T_m - T_a}{G} + a_2 G_0 \left(\frac{T_m - T_a}{G} \right)^2$

$\eta_0 = 0,794$

$a_1 = -4,5 \text{ W/m}^2\text{K}$

$a_2 = -0,009 \text{ W/m}^2\text{K}^2$

Efficiency corresponding to some values of $T^* = (T_m - T_a)/G$:

	$T^* = 0,02$	$T^* = 0,0375$	$T^* = 0,05$
$\eta =$	0,701	0,615	0,551

Collector reference N°:	76d
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A.2.5 Istanteneus efficiency curve based on aperture area

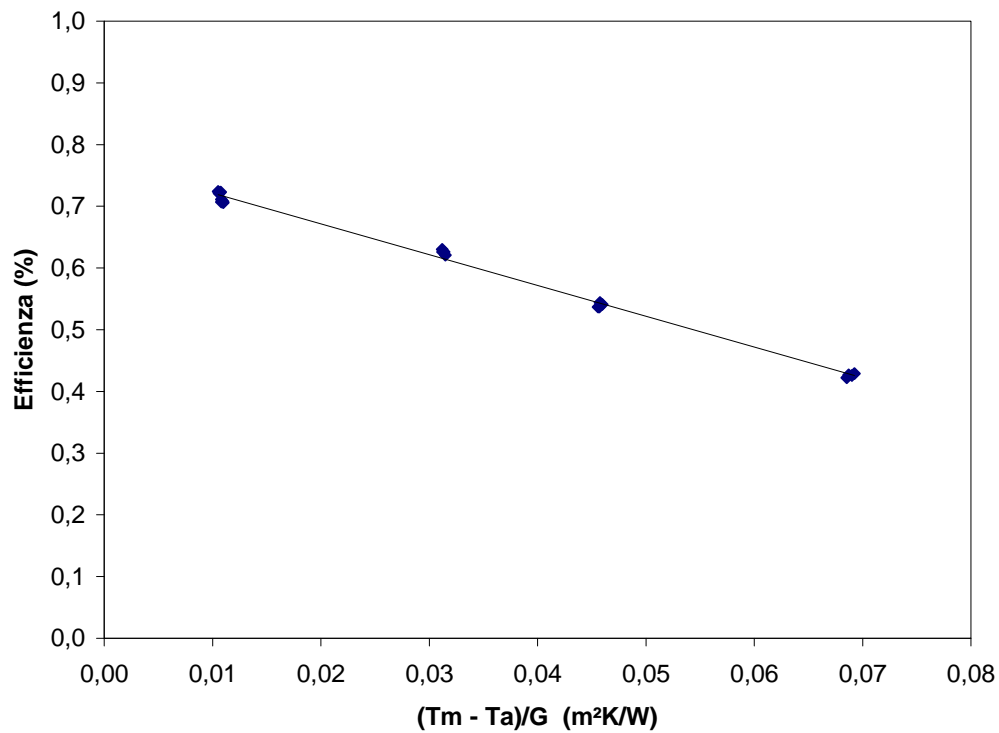
A.2.5.1 Linear fit

Istanteneus efficiency defined as: $\eta = \frac{Q}{AG}$

Total collector area: 2,00 m²

Mean flow rate: 0,04 kg/s

Aperture area: 1,83 m²



Linear regression curve: $\eta = \eta_0 + U_c \frac{T_m - T_a}{G}$

$\eta_0 = 0,772$

$U_c = -5,0 \text{ W/m}^2\text{K}$

Efficiency corresponding to some values of $T^* = (T_m - T_a)/G$:

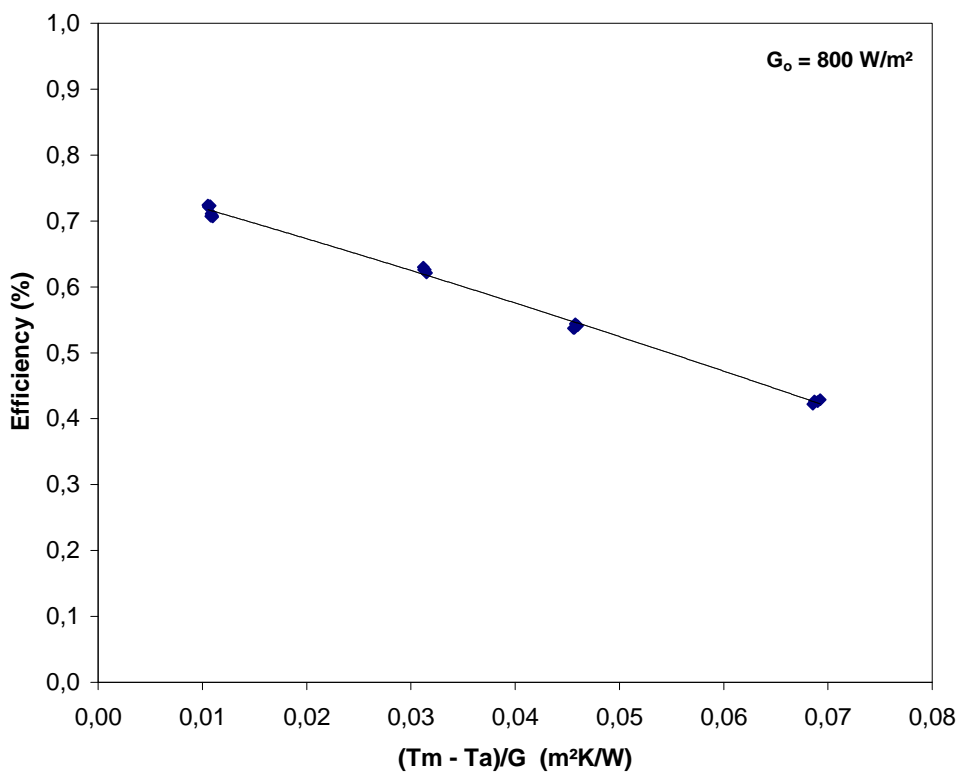
	$T^* = 0,02$	$T^* = 0,0375$	$T^* = 0,05$
$\eta =$	0,672	0,585	0,522

Collector reference N°:	76d
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A.2.5.2 Regressione quadratica

Istantaneous efficiency defined as: $\eta = \frac{Q}{AG}$

Total collector area: 2,00 m²
 Mean flow rate: 0,04 kg/s
 Aperture area: 1,83 m²



Second order curve: $\eta = \eta_0 + a_1 \frac{T_m - T_a}{G} + a_2 G_0 \left(\frac{T_m - T_a}{G} \right)^2$

$\eta_0 = 0,764$
 $a_1 = -4,4 \text{ W/m}^2\text{K}$
 $a_2 = -0,009 \text{ W/m}^2\text{K}^2$

Efficiency corresponding to some values of $T^* = (T_m - T_a)/G$:

	$T^* = 0,02$	$T^* = 0,0375$	$T^* = 0,05$
$\eta =$	0,673	0,589	0,526

Collector reference N°:	76d
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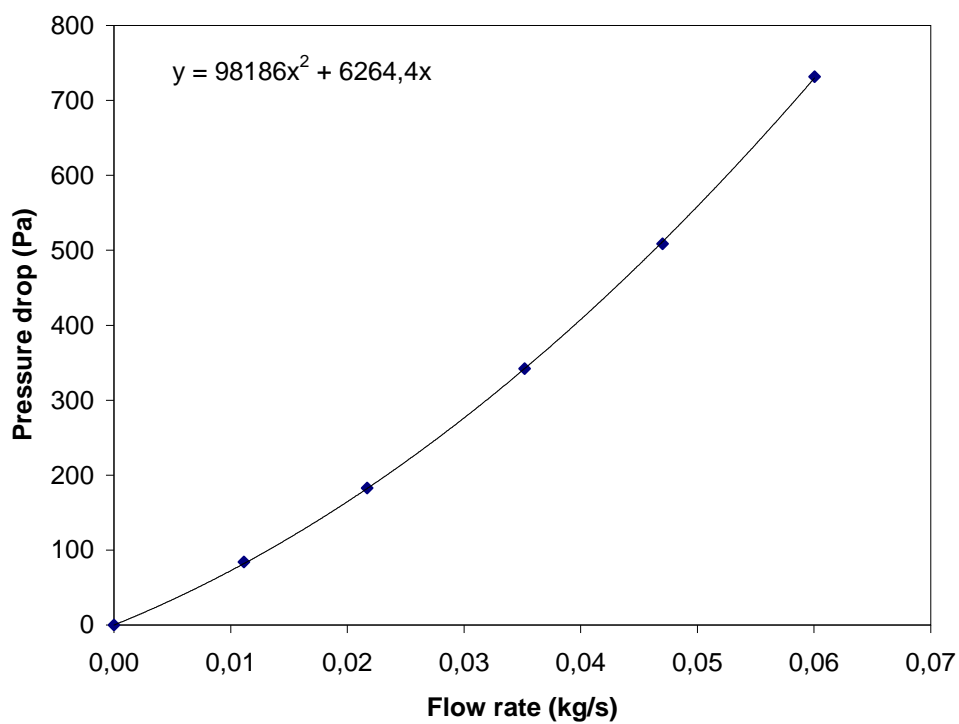
A.3 Pressure drop

Fluid:

Water

Mean fluid temperature:

19,6 °C



Collector reference N°:	76d
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A.4 Time constant

$$\tau_c = 44,8 \pm 1,2 \text{ s}^{(*)}$$

(*) - The uncertainty of measurement has been expressed with a coverage probability of 95 % (k = 2)

A.5 Effective thermal capacity

The effective thermal capacity of collector has been determined in agreement with the test procedure illustrated in Annex J (paragraph J.3).

$$C_p = 17,2 \text{ kJ/K}$$

A.6 IAM (*Incident Angle Modifier*)

$$K_{\theta}(50^{\circ}) = 0,88 \pm 0,04$$

The uncertainty of measurement has been expressed with a coverage probability of 95 % (k = 2)

A.7 Stagnation temperature

Stagnation temperature evaluated at 1000 W/m² of global solar irradiance and 30°C of surrounding air temperature.

$$t_{stg} = 167,1 \text{ }^{\circ}\text{C}$$

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A.8 QDT - Quasi-dynamic test

A.8.1 Mathematical model and results

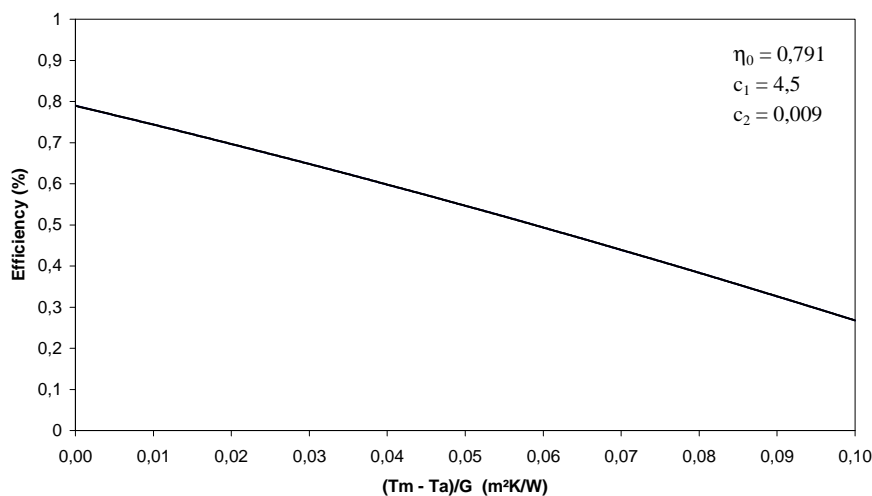
According to the requirements of the test method, the following equation has been used as collector model:

$$\frac{Q}{A} = F'(\tau\alpha)_{en} K_{\theta} G_b + F'(\tau\alpha)_{en} K_{\theta} G_d - c_1(t_m - t_a) - c_2(t_m - t_a)^2 - c_5 \frac{dt_m}{dt}$$

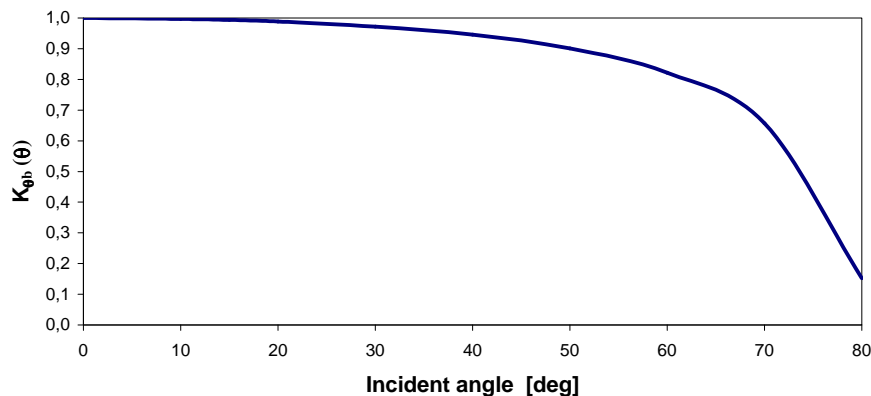
The parameters, based on absorber area ($A_c = 1,76 \text{ m}^2$), have been identified with a multiple linear regression fit on the measured data:

$$\begin{aligned} F'(\tau\alpha)_{en} &= 0,795 \\ K_{\theta d} &= 0,99 \\ c_1 &= 4,5 \quad \text{W/m}^2\text{K} \\ c_2 &= 0,009 \quad \text{W/m}^2\text{K}^2 \\ c_5 &= 6856 \quad \text{J/Km}^2 \end{aligned}$$

Results presented in the form of efficiency curve, evaluated using the following values: $G=800 \text{ W/m}^2$, $G_d=120 \text{ W/m}^2$, $\theta = 15^\circ$, $dt_m/dt = 0$.



A.8.2 $K_{\theta b}(\theta)$ - Incident angle modifier for beam radiation



Collector reference N°:	76d
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Durability and reliability test report

Collector identification

Manufacturer:	MERLONI TERMOSANITARI
Brand name:	TOP
Collector type:	<i>Flat-plate</i>
Year of production:	2005
Serial N°:	3205
Drawing document N°:	-

B.1 Test sequence

Test	Date		Results	
	Start	End		
Internal pressure (1 st test)	27/07/2005	27/07/2005	Passed	
High-temperature resistance	29/07/2005	29/07/2005	Passed	
Exposure	01/08/2005	03/09/2005	Passed	
External thermal shock	First	02/08/2005	02/08/2005	Passed
	Second	30/08/2005	30/08/2005	Passed
Internal thermal shock	First	05/08/2005	05/08/2005	Passed
	Second	29/08/2005	29/08/2005	Passed
Rain penetration	06/10/2005	06/10/2005	Passed	
Freeze resistance	-	-	-	
Internal pressure (2 nd test)	12/01/2006	12/01/2006	Passed	
Mechanical load	12/01/2006	12/01/2006	Passed	
Thermal performance	28/10/2005	11/01/2006	<i>See sections A.2 - A.8</i>	
Impact resistance (optional)	-	-	-	
Final inspection	12/01/2006	12/01/2006	Passed	

Remarks:

Collector reference N°:	76d
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B.2 Internal pressure test: First test

B.2.1 Technical details of collector

B.2.1.1 Collector type

X	Glazed
	Unglazed

B.2.1.2 Maximum collector operating pressure

Maximum pressure specified by manufacturer 600 kPa

B.2.2 Test conditions

Temperature	28,2 °C
Pressure	900 kPa
Duration	15 min

B.2.3 Test results

Test passed - no failures were observed.

Collector reference N°:	76d
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B.4 High-temperature resistance test

B.4.1 Method used:

<input checked="" type="checkbox"/>	Outdoor testing
<input type="checkbox"/>	In solar irradiance simulator

B.4.2 Condizioni di test

B.4.2.1 General

Collector tilt angle	37 deg
Average irradiance during test	1020 W/m ²
Average surrounding air temperature	35,2 °C
Average surrounding air speed	< 1 m/s
Average absorber temperature	- °C
Duration of test	60 min

B.4.3 Test results

Test passed - no failures have been observed.

Remark: In order to avoid modifications that could affect the subsequent tests, the absorber temperature hasn't been monitored during the test.

Collector reference N°:	76d
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B.6 External thermal shock test: First shock

B.6.1 Test conditions

Test performed:

<input checked="" type="checkbox"/>	Outdoor
<input type="checkbox"/>	In solar irradiance simulator

Test combined with exposure test:

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

Test combined with high-temperature resistance test:

<input type="checkbox"/>	Yes
<input checked="" type="checkbox"/>	No

Collector tilt angle (degrees from horizontal):	37 deg
Average irradiance during test:	895 W/m ²
Minimum irradiance during test:	875 W/m ²
Average surrounding air temperature:	32,9 °C
Minimum surrounding air temperature:	32,3 °C
Period elapsed before external thermal shock:	60 min
Flowrate of water spray:	0,038 kg/(s m ²)
Temperature of water spray:	23,8 °C
Duration of water spray:	15 min
Absorber temperature immediately prior to water spray:	- °C

B.6.2 Test results

Test passed - no failures or problems have been observed.

Collector reference N°:	76d
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B.5 Exposure test

B.5.1 Test conditions

Collector tilt angle (degrees from horizontal): 37 deg

In tables B.5.3 and B.5.4 full details should be given of the climatic conditions for all days during the test

B.5.2 Test results

According to the results listed in the following table, no problems or failures have been observed.

Prog.	Collector component	Potential problem	Evaluation
a	Collector box/fasteners	Cracking/warping/corrosion/rain penetration	0
b	Mountings/structure	Strength/safety	0
c	Seals/gaskets	Cracking/adhesion/elasticity	0
d	Cover/reflector	Cracking/crazing/buckling/delamination/warping/outgassing	0
e	Absorber coating	Cracking/crazing/blistering	0
	Absorber tubes and headers	Deformation/corrosion/leakage/loss of bonding	0
	Absorber mountings	Deformation/corrosion	0
f	Insulation	Water retention/ outgassing/ degradation	N.A.

Evaluation scale:

0	No problem
1	Minor problem
2	Severe problem
N.A.	Inspection to establish the condition was not possible

Collector reference N°:	76d
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B.5.3 Climatic conditions for all days during the test

Date	H [MJ/m ²]	T _{amb} [°C]	Rain [mm]	Date	H [MJ/m ²]	T _{amb} [°C]	Rain [mm]
01/08/2005	22,9	30,4	0	21/08/2005	20,9	26,2	0
02/08/2005	21,2	28,4	0	22/08/2005	17,2	24	4,4
03/08/2005	6,5	27	0,2	23/08/2005	16	23,3	0,2
04/08/2005	17,1	25,2	0	24/08/2005	20,9	22,4	0
05/08/2005	20,6	23,4	0	25/08/2005	22,9	22,2	0
06/08/2005	22,8	24,8	0	26/08/2005	22,6	23,7	0
07/08/2005	21,9	24,4	0	27/08/2005	22,4	24,9	0
08/08/2005	6,7	22,9	0	28/08/2005	21,9	24,6	0
09/08/2005	22,9	23	0	29/08/2005	20,7	25,6	0
10/08/2005	22	22,8	0	30/08/2005	10,6	24,9	0,2
11/08/2005	20,9	24,9	0	31/08/2005	14,9	24,1	0
12/08/2005	13,8	25,3	0	01/09/2005	15,6	24,3	0
13/08/2005	22,5	26,8	0	02/09/2005	22,5	25,7	0
14/08/2005	21,7	27,3	0	03/09/2005	22,4	26,5	0
15/08/2005	22,7	26,7	0				
16/08/2005	18,7	22,3	0				
17/08/2005	20,6	22,7	0				
18/08/2005	21,8	23,8	0				
19/08/2005	15,8	23,8	0				
20/08/2005	21,7	24,9	0				
Total: 30 days in which H > 14 MJ/m²							

Collector reference N°:	76d
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B.5.4 Time periods in which irradiance and surrounding air temperature have particular values ($G > 850 \text{ W/m}^2$ e $T_{\text{amb}} > 10^\circ\text{C}$)

Date	G [W/m ²]	T _{amb} [°C]	Time period [min]
01/08/2005	914,1	35,3	4
02/08/2005	883,9	33,5	2,5
04/08/2005	899,6	30,3	0,5
05/08/2005	896,7	27,0	1,5
06/08/2005	938,0	29,7	3,5
07/08/2005	922,2	28,4	3,5
09/08/2005	941,3	28,0	4
10/08/2005	901,2	27,3	3
11/08/2005	877,4	29,4	2
12/08/2005	902,1	28,6	1
13/08/2005	924,7	30,1	3,5
14/08/2005	910,8	31,5	3,5
15/08/2005	936,3	33,4	4
16/08/2005	912,7	27,6	2,5
17/08/2005	924,5	28,3	2
18/08/2005	914,9	28,6	3,5
19/08/2005	895,2	29,5	2
20/08/2005	901,7	30,5	3
21/08/2005	908,2	30,4	3,5
23/08/2005	913,3	29,9	1,5
24/08/2005	928,3	27,8	3,5
25/08/2005	943,9	27,9	4
26/08/2005	938,2	28,7	4
27/08/2005	924,4	30,7	4
28/08/2005	923,2	29,2	3
29/08/2005	914,6	31,6	3
31/08/2005	915,4	26,5	1
02/09/2005	898,9	32,1	3
03/09/2005	888,7	32,5	2,5
Total			82,5 h

Collector reference N°:	76d
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B.7 External thermal shock test: Second shock

B.7.1 Test conditions

Test performed:

<input checked="" type="checkbox"/>	Outdoor
<input type="checkbox"/>	In solar irradiance simulator

Test combined with exposure test:

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

Test combined with high-temperature resistance test:

<input type="checkbox"/>	Yes
<input checked="" type="checkbox"/>	No

Collector tilt angle (degrees from horizontal):	37 deg
Average irradiance during test:	954 W/m ²
Minimum irradiance during test:	914 W/m ²
Average surrounding air temperature:	27,3 °C
Minimum surrounding air temperature:	27 °C
Period elapsed before external thermal shock:	60 min
Flowrate of water spray:	0,04 kg/(s m ²)
Temperature of water spray:	23,6 °C
Duration of water spray:	15 min
Absorber temperature immediately prior to water spray:	- °C

B.7.2 Test results

Test passed - no failures or problems have been observed.

Collector reference N°:	76d
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B.8 Internal thermal shock test: First shock

B.8.1 Test conditions

Test performed:

<input checked="" type="checkbox"/>	Outdoor
<input type="checkbox"/>	In solar irradiance simulator

Test combined with exposure test:

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

Test combined with high-temperature resistance test:

<input type="checkbox"/>	Yes
<input checked="" type="checkbox"/>	No

Collector tilt angle (degrees from horizontal):	37 deg
Average irradiance during test:	983 W/m ²
Minimum irradiance during test:	887 W/m ²
Average surrounding air temperature:	26,7 °C
Minimum surrounding air temperature:	25,4 °C
Period elapsed before internal thermal shock:	60 min
Flowrate of heat transfer fluid:	0,022 kg/(s m ²)
Temperature of heat transfer fluid:	24,8 °C
Duration of heat transfer fluid flow:	6 min
Absorber temperature:	- °C

B.8.2 Test results

Test passed - no failures or problems have been observed.

Collector reference N°:	76d
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B.9 Internal thermal shock test: Second shock

B.9.1 Test conditions

Test performed:

<input checked="" type="checkbox"/>	Outdoor
<input type="checkbox"/>	In solar irradiance simulator

Test combined with exposure test:

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

Test combined with high-temperature resistance test:

<input type="checkbox"/>	Yes
<input checked="" type="checkbox"/>	No

Collector tilt angle (degrees from horizontal):	37 deg
Average irradiance during test:	950 W/m ²
Minimum irradiance during test:	899 W/m ²
Average surrounding air temperature:	25,5 °C
Minimum surrounding air temperature:	24,9 °C
Period elapsed before internal thermal shock:	60 min
Flowrate of heat transfer fluid:	0,023 kg/s m ²
Temperature of heat transfer fluid:	22,3 °C
Duration of heat transfer fluid flow:	8 min
Absorber temperature:	- °C

B.9.2 Test results

Test passed - no failures or problems have been observed.

Collector reference N°:	76d
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B.10 Rain penetration test**B.10.1 Test conditions****B.10.1.1 Collector mounting**

Collector mounted on:

<input type="checkbox"/>	Open frame
<input checked="" type="checkbox"/>	Simulated roof

Collector tilt angle: 30 deg

B.10.1.2 Method used to keep absorber warm

<input checked="" type="checkbox"/>	Hot water circulation
<input type="checkbox"/>	Exposure of collector to solar radiation

B.10.1.3 Water spray

Water spray flowrate	0,1 kg/(s m ²)
Duration of water spray	4 h

B.10.2 Test result

Weight of collector before test	40,105 kg
Weight of collector after test	40,108 kg

Test passed - no visible water penetration inside the collector box has been observed.
 Difference of weight, before and after test, less than 5 g/m².

Collector reference N°:	76d
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B.12 Internal pressure test: Second test

B.12.1 Technical details of collector

B.12.1.1 Collector type

X	Glazed
	Unglazed

B.12.1.2 Maximum collector operating pressure

Maximum pressure specified by manufacturer 600 kPa

B.12.2 Test conditions

Temperature	10,5 °C
Pressure	900 kPa
Duration	15 min

B.12.3 Test results

Test passed - no failures were observed.

Collector reference N°:	76d
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B.14 Mechanical load test

B.14.1 Positive pressure test of the collector cover

B.14.1.1 Method used to apply pressure:

- Loading with gravel or similar material
- Loading with water
- Suction cups
- Pressurisation of collector cover

B.14.1.2 Test conditions

Maximum pressure load: 1000 Pa

B.14.1.3 Test results

Test passed - no failures or damages were observed to the collector cover after the test.

B.14.2 Negative pressure test of fixing between the cover and the collector box

B.14.2.1 Method used to apply pressure:

- Suction cups
- Pressurisation of collector box

B.14.2.2 Test conditions

Maximum pressure load: 1000 Pa

B.14.2.3 Test results

Test passed - no failures or damages were observed to the collector cover or fixing after the test.

B.14.3 Negative pressure test of collector mountings

B.14.3.1 Method used to apply pressure:

- Suction cups
- Air bags

B.14.3.2 Test conditions

Maximum pressure load: 1000 Pa

B.14.3.3 Test results

Test passed - no failures or damages were observed to the collector mounting fixtures after the test.

Note: test conducted at the same time of the negative pressure test of fixing between the cover and the collector box.

Collector reference N°:	76d
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B.17 Final inspection

Prog.	Collector component	Potential problem	Evaluation
a	Collector box/fasteners	Cracking/warping/corrosion/rain penetration	0
b	Mountings/structure	Strength/safety	0
c	Seals/gaskets	Cracking/adhesion/elasticity	0
d	Cover/reflector	Cracking/crazing/buckling/delamination/warping/outgassing	0
e	Absorber coating	Cracking/crazing/blistering	0
	Absorber tubes and headers	Deformation/corrosion/leakage/loss of bonding	0
	Absorber mountings	Deformation/corrosion	0
f	Insulation	Water retention/ outgassing/ degradation	N.A.

Evaluation scale:

0	No problem
1	Minor problem
2	Severe problem
N.A.	Inspection to establish the condition was not possible

Collector reference N°:	76d
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Symbols and units

Symbol	Description	Unit
a_1	Algebraic constant	W/m ² K
a_2	Algebraic constant	W/m ² K ²
A_G	Gross area of collector	m ²
A_a	Aperture area of collector	m ²
A_C	Absorber area of collector	m ²
C_p	Specific heat capacity of heat transfer fluid	J/kgK
G	Global solar irradiance	W/m ²
G_b	Direct solar irradiance	W/m ²
G_d	Diffuse solar irradiance	W/m ²
E_l	Longwave irradiance ($\lambda > 3 \mu\text{m}$)	W/m ²
m	Mass flowrate of heat transfer fluid	kg/s
Q	Useful power extracted from 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
T^*	Reduced temperature difference = $(T_m - T_a)/G$	m ² K/W
U_C	Overall heat loss coefficient	W/m ² K
u	Surrounding air speed	m/s
η	Collector efficiency	-
η_0	Zero-loss collector efficiency	-
τ_c	Collector time constant	sec
C_p	Effective thermal capacity of collector	kJ/K
K_θ	Incidence angle modifier	-
$K_{\theta b}(\theta)$	Incidence angle modifier for direct radiation	-
$K_{\theta d}$	Incidence angle modifier for diffuse radiation	-
F'	Collector efficiency factor	-
$(\tau\alpha)_{en}$	Effective transmittance-absorptance product	-
c_1	Algebraic constant (heat loss coefficient)	W/m ² K
c_2	Algebraic constant (temperature dependence of the heat loss coefficient)	W/m ² K ²
c_5	Algebraic constant (effective thermal capacity)	J/Km ²
t_{stg}	Stagnation temperature	°C