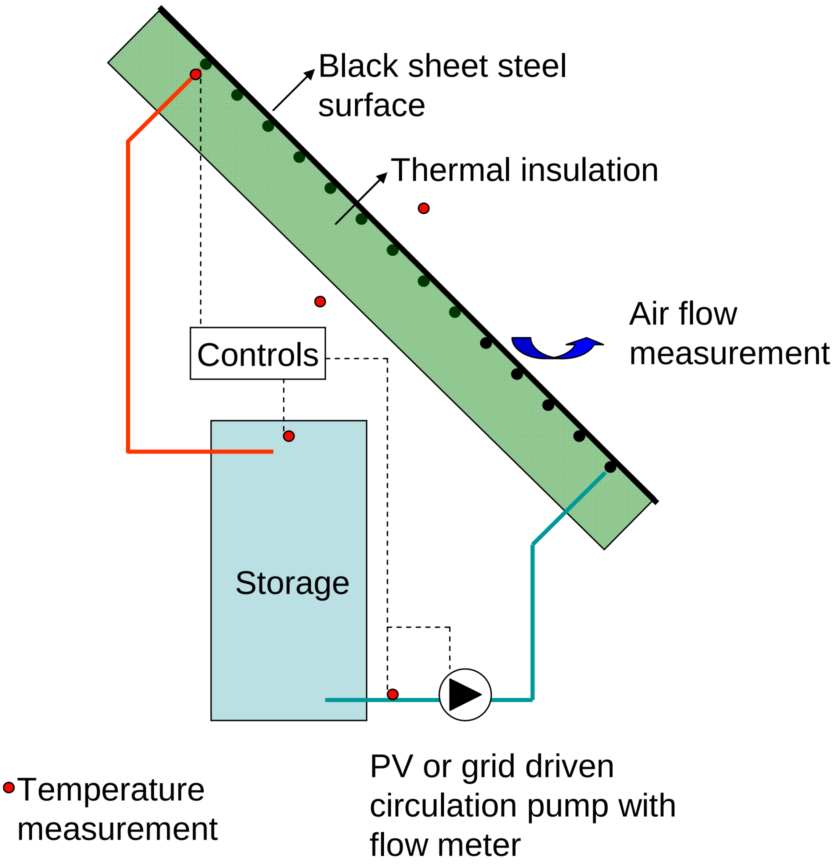
RESEARCH REPORT



RENOVATION OF BUILDINGS USING STEEL TECHNOLOGIES RFSR-CT-2007-0043

Performance of façade/roof integrated solar collector

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Confidentiality: Final report

Contents

1 Introduction

The integration of the solar collectors in the roof and façade systems is very interested option for improving energy efficiency of the traditional applications. The integration of the applications will combine several functions. The roof or façade system has the structural performance as primary function. The structure offers protection for climate conditions (wind, rain, snow, temperature). Adding the energy production aspect in the application needs integration in the energy system as well. Figure 1 present the principle of the façade or roof integrated solar heat collector system.

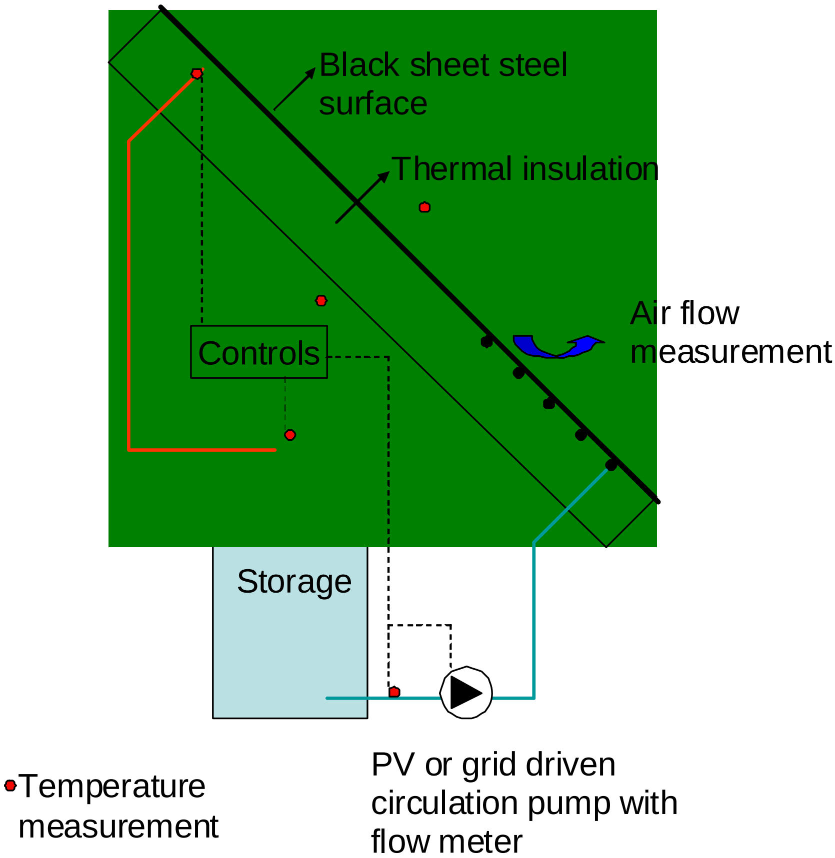


Figure 1. Principle of roof integrated solar heat collector.

2 Goal

The goal of the study was to present the thermal and solar performance of the roof or façade integrated solar heat collector. The collector systems was designed and constructed for the purpose of the study and the structural and thermal performance design was not optimised. The study shows the potential for the application and the structure will be optimised in future studies.

3 Experimental study

The thermal and solar performance of the roof or façade integrated solar heat collector was studied by the following steps:
1. Design of structure and liquid circuit
2. Selection of measurement method => VTT solar hotbox
3. Construction and installation
4. Measurements
5. Data analysis
6. Results and conclusions

3.1 Design of structure and liquid circuit

The design of the structure is presented in figures 2-4.

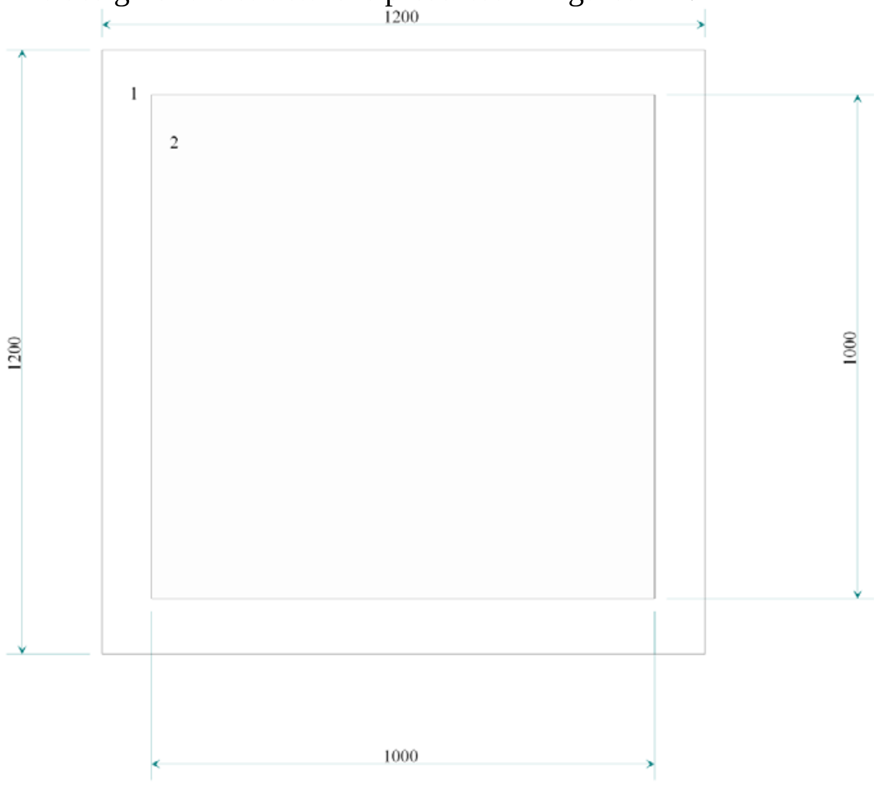


Figure 2. The collector #2 (1,0 m x 1,0 m) and frame #1 areas (1,2 m x 1,2). Places for the connection pipes #3.

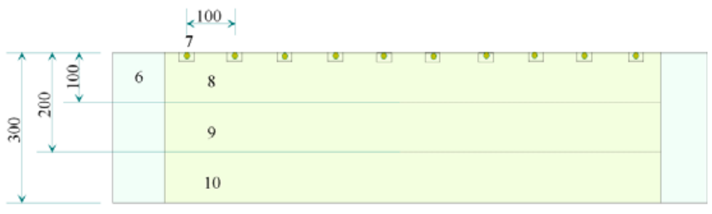
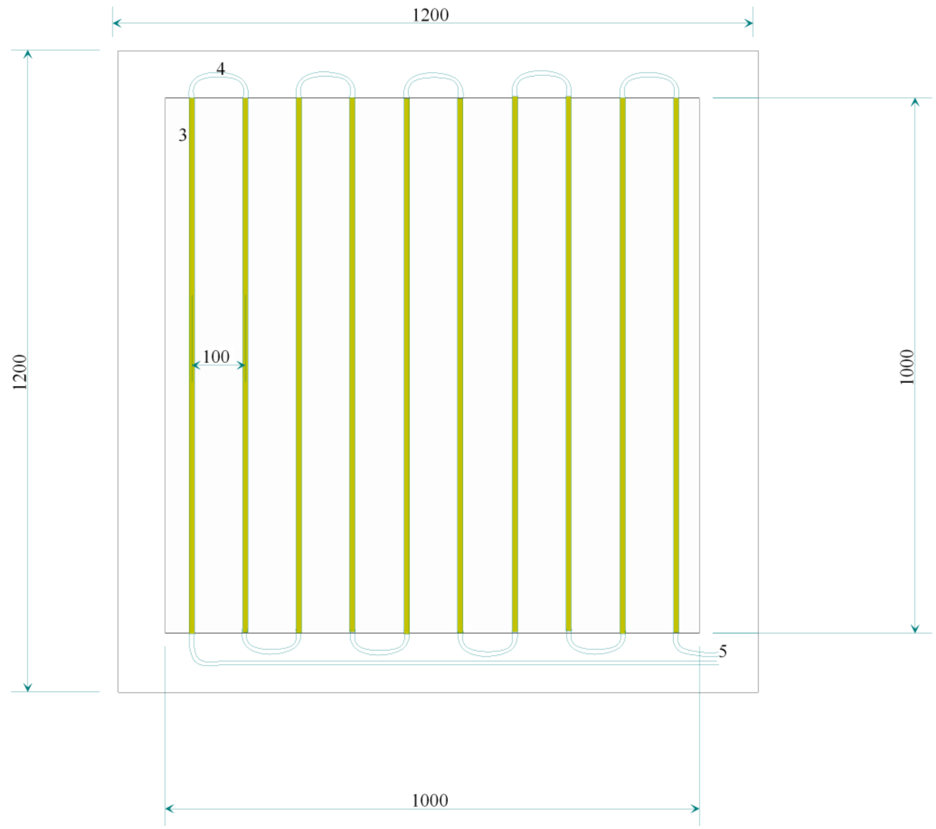


Figure 3. Cross section of the collector. Insulated additional frame #6, tubes #7 in the channel in insulation #8,#9,#10



3. Kupariputket kontaktissa teräskatetta vasten
4. Kupariputket käännetään reunaeristyksen sisässä
5. Vesikierto sisään ja ulos; liittimet

Figure 4. The liquid circulation tubes #4 behind the external surface in contact with cladding (black painted steel).

The area of the tested roof façade is 1,0 m x 1,0 m^2. The liquid circulation tubes change the flowing direction and are bended inside the additional framing between the sample and mounting wall of the test cell. The dimensions of the framing are 1,2 x 1,2 m^2.

3.2 Measurement method – VTT solar hotbox

The measurements for the vertical façade were performed using VTT solar simulator lamp installed in hotbox chamber, figure 5. The measured sample is installed in the mounting wall between controlled warm and cold chambers. The external surface is radiated with solar simulator lamp having spectrum near solar spectrum. The heat balance of the metering chamber determines the heat flow transmitting the sample. The heat balance of the metering chamber and the external solar radiation determines the total solar energy transmittance of the sample. In case of solar collectors, the heat flow transmitting to liquid circuit is determined.

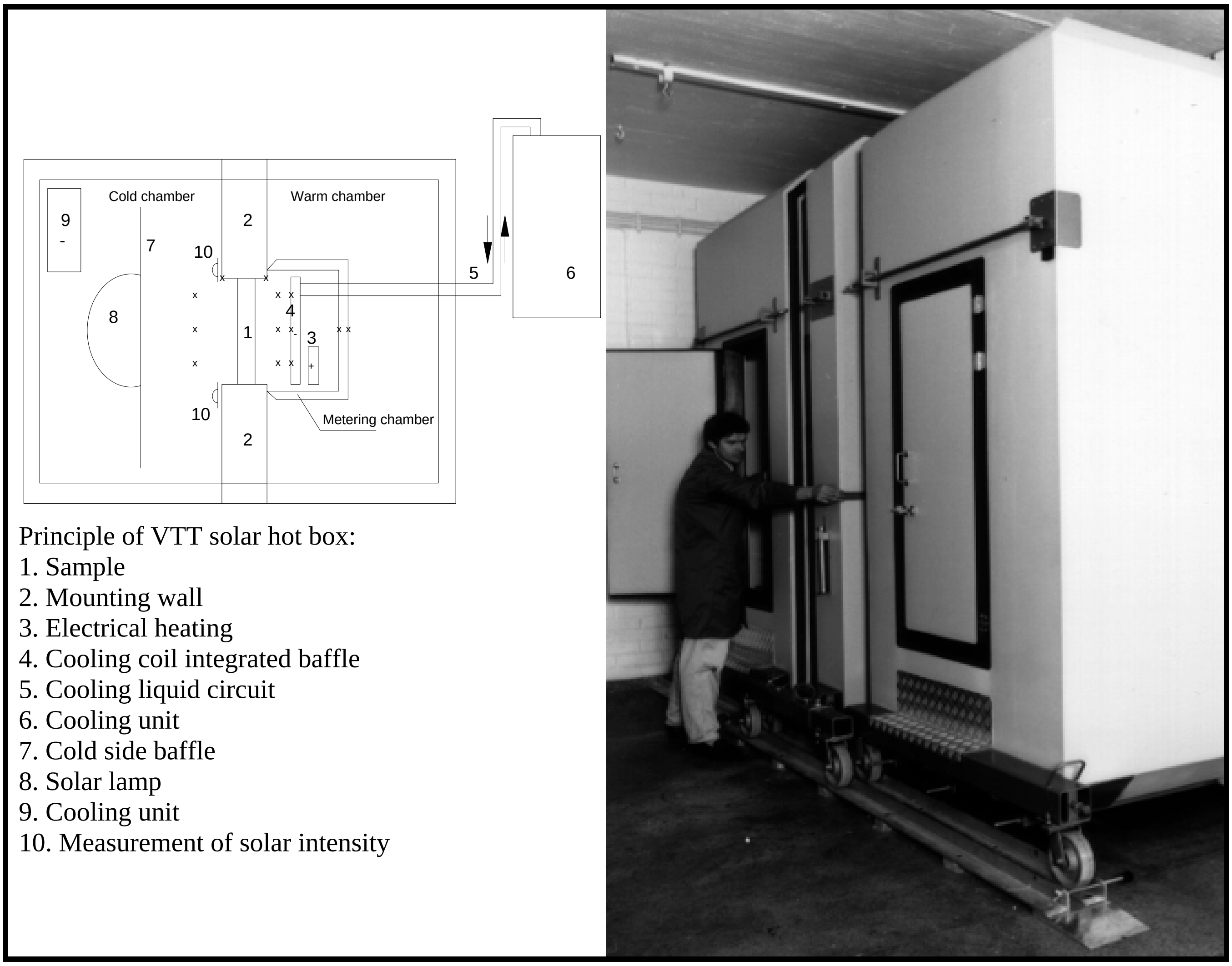


Figure 5. The test equipment for testing of total solar energy transmittance (g-value) and efficiency of solar collectors. Collector (1=sample in figure) water circuit is not presented in figure.

The efficiency and dynamics of the solar collector was measured during different temperature differences (the temperature difference between the circuited water and the environment). The solar collector mounted in vertical wall was irradiated by solar simulator lamp producing the average intensity of about 640…690 W/m^2 in the vertical surface. Based on the measurements the thermal efficiency of the solar collector was calculated dividing the energy transmitting to the circulated water by the solar radiation incident to external surface of the collector. The measurements were performed using VTT Solar hotbox having solar simulator lamp 2,5 kW (Appendix 1). In the measurements the principles of standard SFS-EN 12975-2 +AC /1/ was applied as far as possible.

The measured results has been analysed based on the priciples in standard SFS-EN 12975 +AC /1/:

The efficiency is

$$\eta = \frac{\Phi}{AG} \qquad (1)$$

where

P is	heat flow transmitting to the circulated liquid
A	area of the collector
G	solar radiation intensity in the external surface

$$\Phi = q_m c_p \Delta T \qquad (2)$$

where

q_m is	mass flow rate of the circulated liquid
c_p	specific heat of the circulated liquid
ΔT	The temperature increase in solar collector, temperature difference

The instantaneous efficiency of the collector η can be expressed as function of the difference between liquid temperature and environmental temperature

$$\eta = \eta_0 - a_1 T_m^* - a_2 G T_m^{*2} \qquad (3)$$

$$T_m^* = \frac{T_m - T_y}{G} \qquad (4)$$

T_m-T_y is the difference between the average collector water temperature and environmental temperature.

3.3 Construction and installation

Figures 6-10 present the construction of the solar collector, which was installed in vertical position in the solar hotbox device.

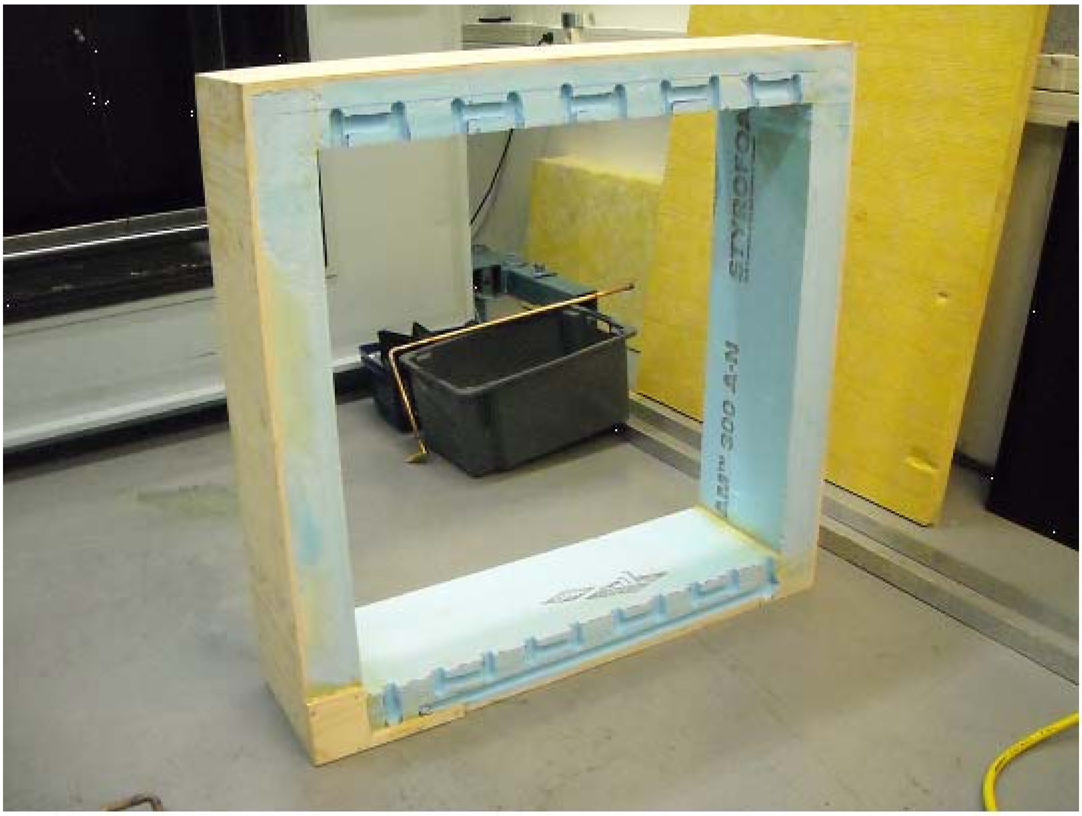


Figure 6. Frame between the mounting wall and the sample.

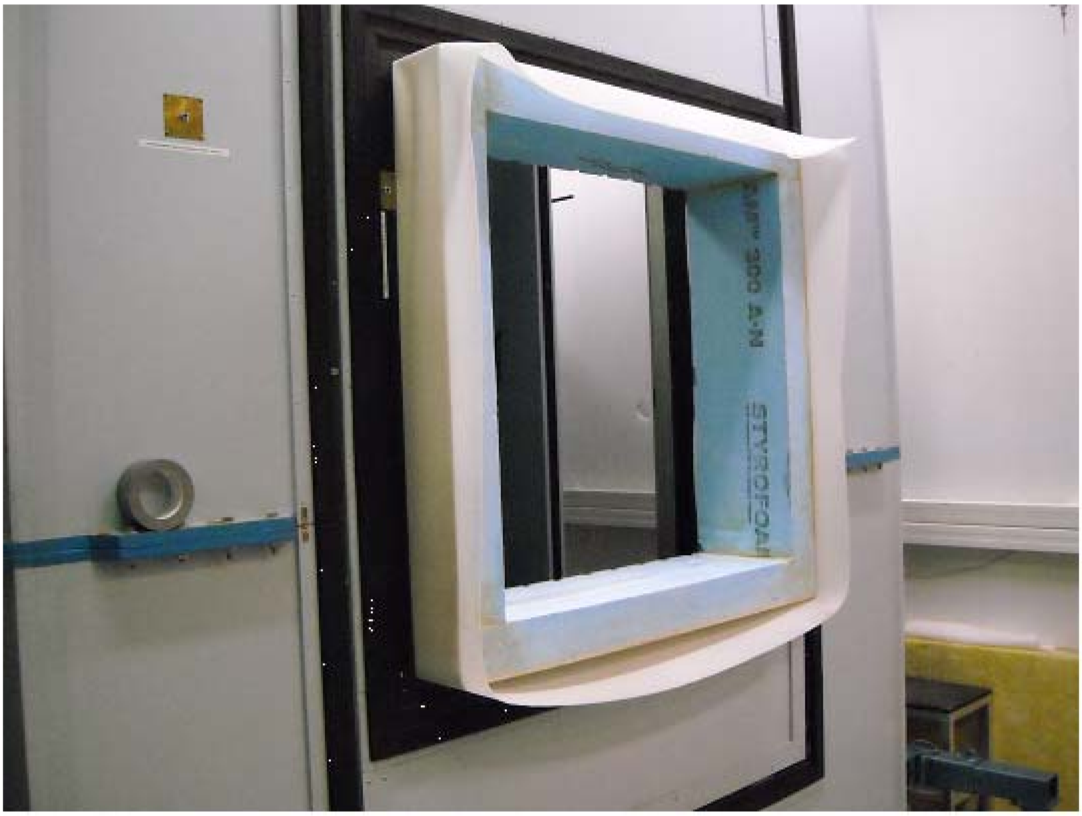


Figure 7. The frame was installed in the test cell facade.

Figure 8. The channels for liquid circulation tubes in the external surface of the thermal insulation.

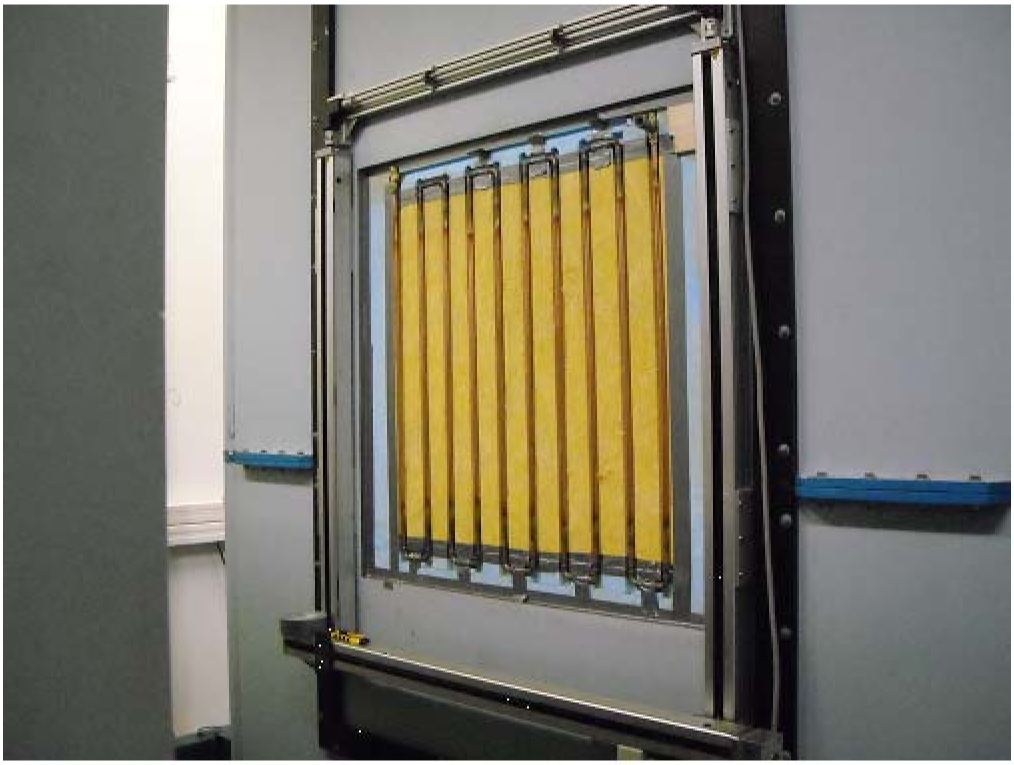


Figure 9. The liquid circulation tubes in the external surface of the thermal insulation.

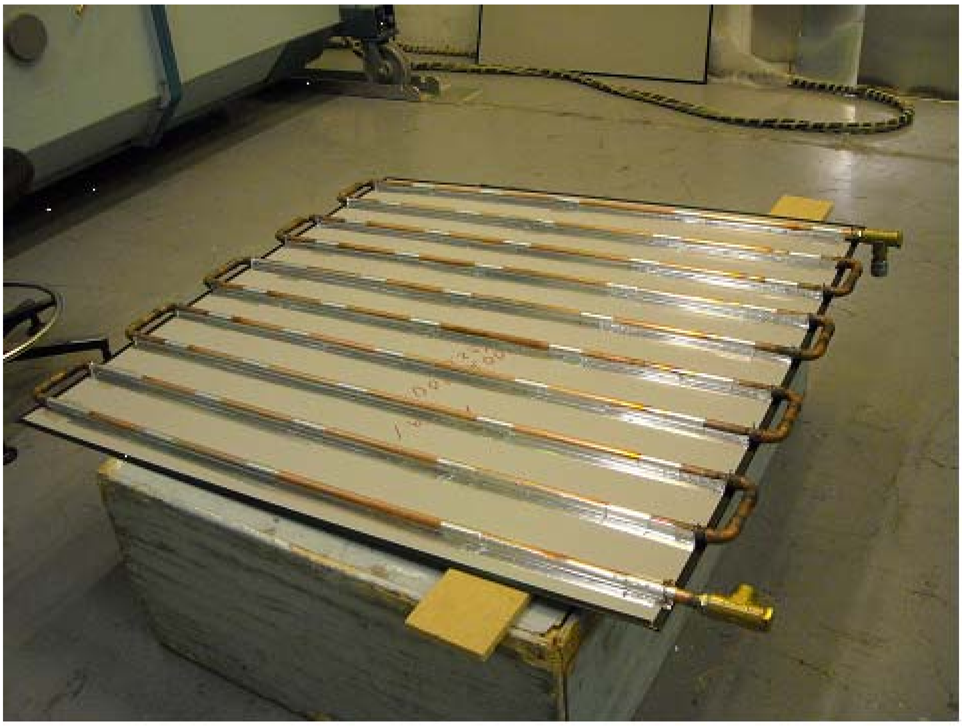


Figure 10. The liquid circulation tubes (copper pipes) attached to external metal sheet with aluminium tape.

Figure 11. External metal sheet and copper pipes installed in component.

Figure 12. Copper pipes connected to liquid circuit (water in test case). By-pass circuit was used to balance mass flow rate of the collector

The solar intensity was measured at external surface with the movable CM11 and fixed CM11 in upper right corner (figure 13).

Figure 13. Measurements for the solar radiation intensity.

The main measured values were mass flow rate, temperatures in water inlet and outlet, temperatures at different surfaces and layers and in the air and solar radiation in the external side of the sample.

4 Measurements and analysis

The following measurements were performed (exact values in the results section):

1. Basic thermal transmittance, U-value, for the component (in dark conditions, no solar radiation) and
2. Efficiency of the collector in different conditions (with solar radiation) at the conditions:
   - Indoor Tint ~20…22 ^{o}C
   - Outdoor Text ~0…1 ^{o}C …10 ^{o}C
   - Water mass flow rate 0,005…0,012 kg/s
   - Water temperature Twater,in= ~ 5…10…15 …20 ^{o}C

Table 1 presents the measured values in details in different situations.

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Table 1. The measured values in details in different situations, and calculated thermal efficiency n. The symbols in the table are:

d is	*thickness of the insulation in the wall (20 or 30 cm)*
Twi	*water inlet temperature*
Two	*water outlet temperature*
Qcollector	*heat input in the collector liquid, see eq. (2)*
Gsol	*solar radiation intensity (W/m2)*
Tm	*mean temperature of the collector*
Tcold	*outdoor air temperature*
Tcold,pieli	*outdoor surface temperature in the edge surface*
Tcold,baffle	*external baffle temperature*
Twarm, baffle	*internal (warm side) baffle temperature*
Efficiency n	*efficiency, see eq. (1)*

Insulation d (cm)	qm (kg/s)	Twi	Two	Two-Twi	Qcollector	Gsol	Tm	Tcold	Tcold,pieli	Tcold,baffl	Twarm,baf	Twarm,bac	Tm-Tcold	efficiency n (qm=0,012 kg/s)
30	0,012	4,76	10,63	5,87	303,7	640	7,69	0,98	4,95	8,28	21,79	21,55	6,71	0,474
30	0,012	8,51	13,64	5,13	265,5	646	11,08	1,02	4,89	8,16	21,88	21,63	10,06	0,411
30	0,013	11,82	16,47	4,65	244,0	674	14,14	1,57	6,23	8,26	21,90	21,67	12,58	0,362
	qm (kg/s)												Tm-Tcold	n (qm=0,004/6)
30	0,006	5,14	15,70	10,56	272,7	623	10,42		6,72	8,37	22,05	21,81	10,42	0,438
30	0,005	13,77	22,66	8,89	171,0	675	18,22	1,89	6,72	8,47	21,96	21,75	16,33	0,253
30	0,004	18,42	25,79	7,37	138,0	690	22,10	1,78	6,27	8,53	21,89	21,72	20,32	0,200
	qm (kg/s)												Tm-Tcold	n (qm=0,008)
20	0,008	6,01	13,95	7,93	256,4	660	9,98	1,22	6,62	8,02	21,86	21,26	8,76	0,388
20	0,008	10,07	16,69	6,62	212,0	660	13,38	1,00	6,79	7,63	21,88	21,36	12,38	0,321
20	0,008	18,31	23,08	4,77	159,4	660	20,70	1,72	9,17	8,35	21,92	21,52	18,97	0,242
	qm (kg/s)												Tm-Tcold	n (qm=0,008)
20	0,008	7,20	18,51	11,31	357,1	660	12,86	10,68	15,05	18,81	22,88	22,39	2,18	0,541
20	0,007	11,88	22,12	10,24	314,6	660	17,00	11,15	16,27	18,48	22,89	22,51	5,85	0,477
20	0,008	19,97	27,61	7,64	245,2	660	23,79	11,47	17,74	18,36	22,81	22,57	12,32	0,372

All the results (table 1) are presented in figure 14.

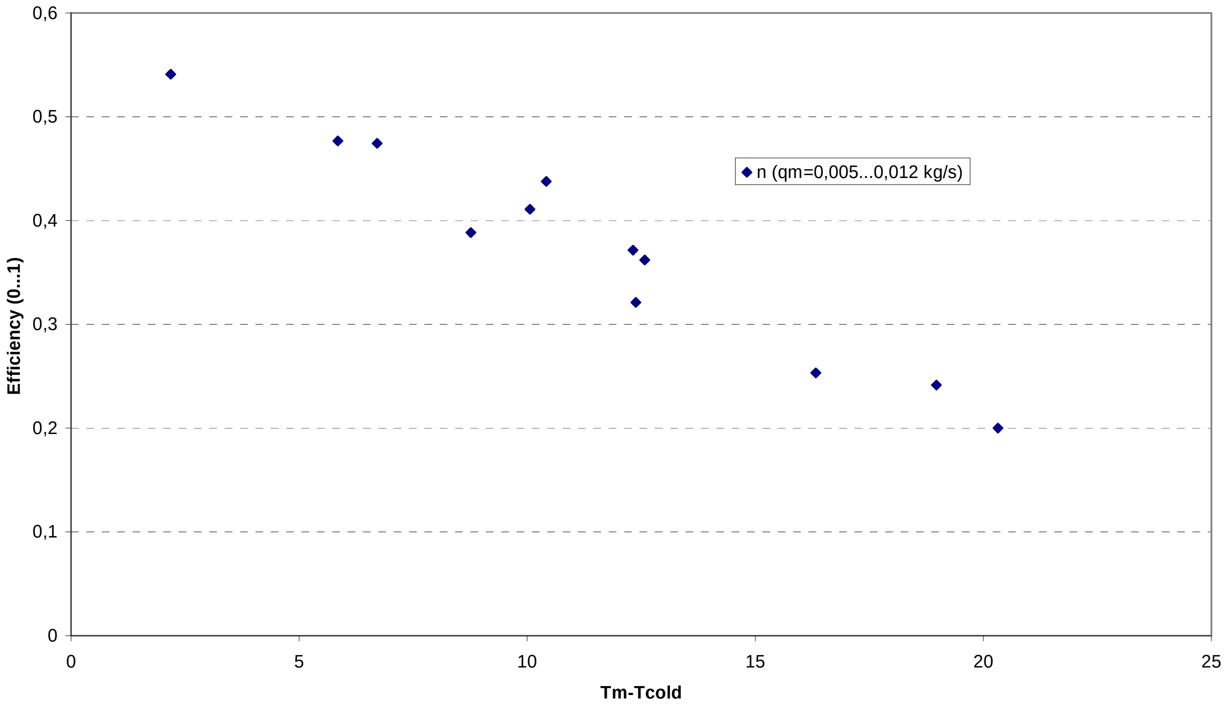

Figure 14. The thermal efficiency of the solar thermal collector integrated in vertical façade presented as function of Tm-Tcold. The water flow rate varies between 0,005…0,012 kg/s.

5 Conclusions

The efficiency was measured only for some single mass flow rates and not for all the performance area.

The main conclusions based on the measured results are:

The efficiency at mass flow rates 0,005…0,012 kg/s at outdoor temperatures 0…10 ^{o}C is 20…55 %, leading to thermal efficiency η 0~55 %. The result depend on the conditions

- Lower water inlet temperature T_{wi} => higher efficiency
- Higher mass flow rate => higher efficiency
- Higher outdoor air temperature => higher efficiency (due to lower losses)

In this study the structure of the component was not optimised. The optimised construction with well designed liquid circulation, tube spacing and dimensions, optimal mass flow rate and better contact between the tubes and external cladding would give higher thermal efficiency. The optimisation of the structure is the task of the future studies.

References

/1/ SFS-EN 12975-2 +AC. Aurinkolämpöjärjestelmät ja -komponentit. Aurinkolämpökeräimet. Osa 2. Testausmenetelmät. Thermal solar systems and components. Solar Collectors. Part 2. Test methods. Approved 2001-08-20. 1+144+3 pages.