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SOLTRAIN II – SOLAR WATER HEATING SYSTEM TEST AND DEMONSTRATION FACILITY

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ABSTRACT

The Centre for Renewable and Sustainable Energy Studies of Stellenbosch University has implemented a test and demonstration facility for solar water heating systems. The purpose of the facility is to conduct the performance testing of the solar water heating systems. The initial performance tests on the reference collector have been conducted and the results have been used to validate the installed facility.

INTRODUCTION

The Centre for Renewable and Sustainable Energy Studies (CRSES) of Stellenbosch University has implemented a test and demonstration facility for solar water heating systems (SWH). The test facility is part of the Soltrain ll project. Soltrain is financed by the Austrian Development Agency (ADA) and it is implemented by AEE – Institute for Sustainable Technologies from Austria.

This paper reports on the test facility that is installed. This will be done by giving background to the project, detailing the configuration of the test facility, test methodology, results, conformance to the DIN standard and subsequent to that will be the conclusion.

OBJECTIVE

The objective of the Soltrain ll test and demonstration facility is to conduct the performance testing of the SWH. The performance of the SWH system is expressed by the efficiency curve of the collector. This is the approach that is adopted for this project. The design and construction of the test facility is informed by the DIN EN 12975-2:2006-06 standard. The idea is to conform to the standard and perform tests based on the standard.

Figure 1: SWH test and demonstration facility

BACKGROUND

The facility is constructed on the dedicated open air Solar Roof Laboratory (SRL). The 28 x 13 m SRL is housed on the second level roof with a control room looking out onto the roof area. The collector frames include grid platforms of 2 x 2 m to accommodate different collector designs, adjustable from 0 °C to 90 °C. see Figure 1.

The Soltrain ll test facility configuration consists of two loops:

1. Closed Loop Water Reticulation System

The function of the closed loop water reticulation system is to act as energy dump source by extracting thermal energy from the collector closed loop. The reticulation system supplies water at a constant pressure adjustable between 2.5 and 4 bar. The closed loop water reticulation system was installed during Soltrain l and it has been adopted and used for Soltrain ll. It consists of the following components. See Figure 2.

- Storage Tank
- Heat Exchanger
- Three way valve
- 6 stage Pump with VSD
- 3 × Solenoid valves (Supply)
- 3 × Solenoid valves (Return)
- 1 × Solenoid valve (bypass)
- Thermocouples
- Pressure Transducers
- Programmable Logic Controller (PLC)

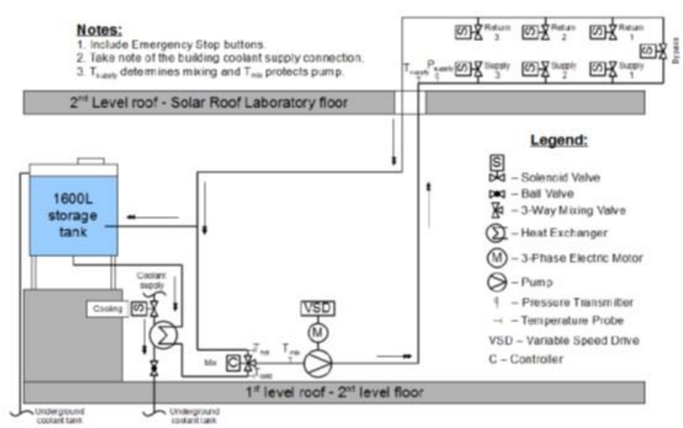

Figure 2: Closed loop water reticulation system configuration

2. Reference collector testing facility

The reference collector testing facility includes equipment to mount the collector, circulate water, to measure the solar resource, to measure the water temperature at all relevant points and measure water flow rate. All the equipment was bought specifically for the Soltrain ll test facility.

The measured parameters are used to develop the efficiency curve of the collector in order to determine the thermal performance. The Table 1 shows the Soltrain ll equipment and the specification.

Table 1: Soltrain ll equipment and specification

Equipment	Specification
Water Circulation Pump	SEG – GPD25-4S (60 W – 11/2" circulation pump)
Electromagnetic Flow meter	50H08-3AE4/0 (Promag 50H08, DN08 5/16")
Thermocouples	8 x T-type thermocouples
Radiation Shield with TC Pair	
Pyranometer	CMP 11 Pyranometer, ISO Secondary Standard
Data logging and control instrument (from Soltrain l)	Data logging and control instrument (National Instrument/NI – Compact DAQ 9188)
Heat exchanger	Brazed plate heat exchanger (CBH16-9H) – 3 kW
Temperature regulator (in-line heating element)	Immersion Heater – 3 x 1kW, 230V each. Immersion Length = 380mm 1 X 1 – Station control box with Gefran 600, isolator switch, 10 A ultrarapid fuse + Solid State Relay
Expansion tank	SEG – AG35 2.5 bar (120 0C max temp) 35 litre expansion tank
Air release valve	1/2" air release valve
Pressure valve	4 bar TP valve female
Pressure gauge	63 mm diameter pressure gauge (0 – 10 bar)
Flow control valve	2 x manually operated integral bonnet needle valves with 4.4 mm orifice
Inline filter	1/2" Inline filter – 200 µm nominal pore size
Pneumatic control – Three way valve	Three-way (mixing valve). Electric actuator

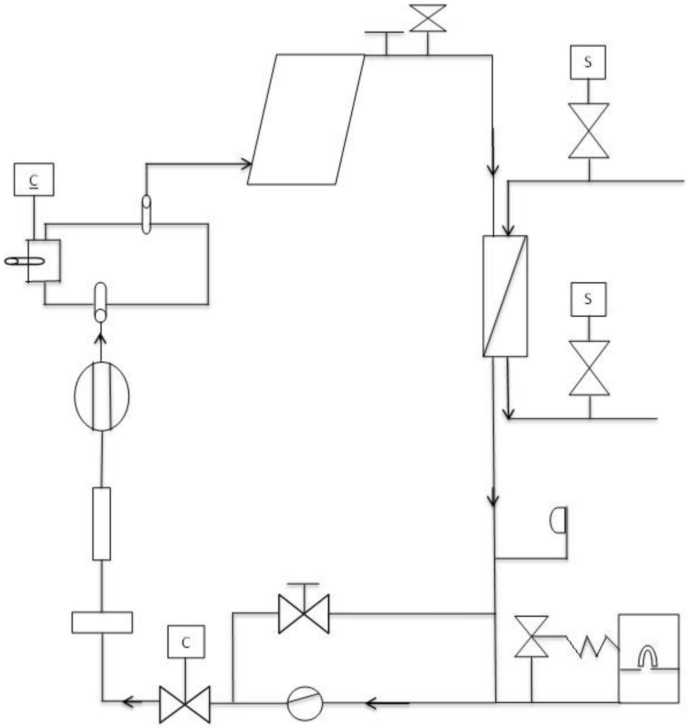

Figure 3: Reference collector test facility loop

The Figure 2 shows the closed water reticulation system. The Figure 3 shows the reference collector system on the solar roof. The two loops are connected by a heat exchanger. The supply and the return solenoid valves are connected to the heat exchanger. The legend of the Figure 3 components can be found in Figure 4.

3. Mixing valve integration point

Next to the SWH test and demonstration facility, there is a pump indirect SWH system. The system has a 600 litre insulated, stratified tank. For the performance tests, the SWH pump system is connected to the SWH test facility. This is done by using a three-way mixing valve - electrical actuator controlled. The objective of doing that is to obtain high temperature water that will be used as input water to the reference collector. Figure 4 shows the configuration of the two systems – SWH indirect pump system and the SWH test facility.

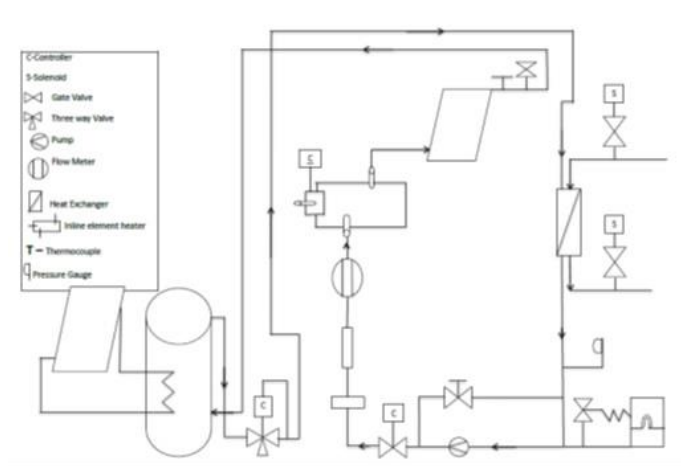

Figure 4: Reference collector test facility loop and the pump indirect SWH system

DESCRIPTION OF COLLECTOR COMPONENTS

The Table 2 shows the list of collector specification that have been used as the reference collector during the test.

Table 2: Reference collector specification

Description	Details
Type	Flat plate
Brand name	ALPIN RK 2300
Serial no	2009/42 0579
Collector reference	RK 2300 Mediterano
Total area	2.34 m^2
Aperture area	2.23 m^2
Absorber area	2.14 m^2
Material of the cover	solar safety glass
Number of covers	1
Thickness of the cover	3.2 mm
Weight empty	32 kg
Volume of fluid	1.60 litre
Heat transfer fluid	Water
Material of the absorber sheet	Aluminium
Thickness of the absorber sheet	0.4 mm
Kind of selective coating	Highly sele
Absorptivity coefficient	95 %
Emissivity coefficient	5 %
Material of the absorber pipe	Copper
Outer diameter	8 mm
Collector dimensions Height, width, depth	2000 x 1170 x 73 mm
Thickness of the insulation at the back	40 mm
Material	Mineral wool heat insulation

Material of the casing	Aluminium frame
Maximum fluid pressure	10 bar
Operating fluid pressure	
Maximum service temperature	Not defined
Maximum stagnation temperature	210 °C
Maximum wind load	150 km/h
Recommended tilt angle	15 ° / 75 °
Flow range recommendations	Not defined

TEST METHOD

The efficiency of the collector is defined as the ratio of the absorbed energy to the available solar energy. The absorbed energy is the energy transferred from the collector to the heat transfer fluid and the solar energy is the in-plane incident radiant energy onto the collector. The efficiency curve is obtained by plotting it as a function of the ratio of the temperature difference of the average temperature of the heat transfer fluid of the collector and the ambient temperature (Tm – Ta) divided by the incident radiant energy (G). The efficiency is calculated using the equation (1). The measured parameters are used to develop the efficiency curve of the collector in order to determine the thermal performance.

$$\eta_{collector} = \eta_o - a_1.\frac{(t_m - t_a)}{G} - a_2.\frac{(t_m - t_a)^2}{G} \quad (1)$$

η_0	maximum efficiency (efficiency at $t_m = t_a$)	
a_1	linear heat loss coefficient	$\frac{W}{m^2.K}$
a_2	quadratic heat loss coefficient	$\frac{W}{m^2.K^2}$
t_m	mean collector temperature	°C
t_a	ambient temperature	°C
G	incident radiation energy (global radiation)	$\frac{W}{m^2}$

Table 3: Collector efficiency parameters

Boundary conditions	
Test method	Outdoor, steady state
Collector tilt	45 °
Mean irradiation	1000 W/m^2
Mean flow rate	2.6 l/min
Kind of fluid	Water

RESULTS

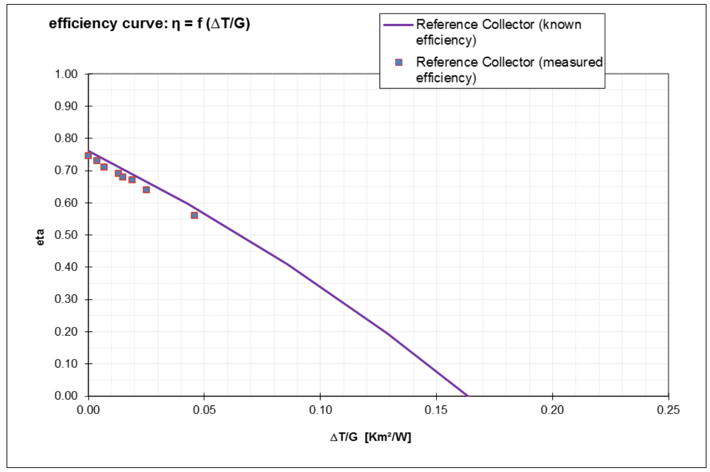

Figure 5: Reference collector efficiency curve (measured and known)

The Figure 5 shows the efficiency curve of the reference collector and the measured collector efficiency. The tests were conducted at a flow rate of 0.02 kg/s/m2 of the collector (2.6 l/min for the reference collector), as per the DIN 12975-2 standard. The solar radiation was at 1 000 W/m2. The maximum input temperature of the working fluid in the collector during the tests was 55 °C. The next step is to increase the input temperature of the working fluid in order to obtain the stagnation temperature of the collector.

The Table 4 shows the comparisons of the reference collector known efficiency and the measured efficiency. This is based on these test conditions of the conducted performance test – 25 °C, 30 °C, 35 °C, 40 °C, 45 °C, 50 °C and 55 °C. For these points, the graph shows the_accuracy of the measured efficiency against the known reference collector efficiency.

Table 4: Reference collector efficiency comparison

Test value (input temperature)	Measured – eta	Reference - eta	Accuracy (%)
25 °C	0.73	0.75	97%
30 °C	0.71	0.73	97%
35 °C	0.69	0.71	97%
40 °C	0.68	0.7	97%
45 °C	0.67	0.68	99%
50 °C	0.64	0.67	96%
55 °C	0.56	0.57	98%

The Soltrain ll test facility configuration is adopted from the DIN 12975-2 standard. The DIN standard states the necessary components for thermal performance testing of the SWH. All the components, as required by the DIN, were sourced for the test facility. Key parameters from the standard are: flow rate measurement and the temperature measurement. The standard requires a flow rate uncertainty of ± 1 %. The procured flow meter specification shows that it is adequate to obtain the required accuracy. The standard requires that the temperature measurement accuracy of 0.1 K be maintained. For the test facility, the T-type thermocouples were used which had an accuracy of 0.5 K. Pt 100 thermocouples would be adequate to maintain the 0.1 K accuracy. However, experience of using T-type thermocouples shows that they are adequate for the performance testing.

CONCLUSION

The installation is complete and the performance tests have been conducted on the reference collector. This is based on these test conditions of the conducted performance test – 25 °C, 30 °C, 35 °C, 40 °C, 45 °C, 50 °C and 55 °C for the fluid input temperature. Initial analysis shows that measured results correlate with the known reference collector efficiency. The next step is to increase the input temperature of the working fluid in order to obtain the stagnation temperature of the collector.

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