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STUDY OF THE EFFICIENCY AND OTHER WORKING PARAMETERS OF SOLAR COLLECTORS

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ABSTRACT: *The efficiency of a solar collector is the function of the solar irradiation intensity and the temperature different between the collector and the ambient air. By the measurements we wanted to determinate the efficiency function as in a wide range as we can. We did the measurements in outdoor conditions, we have not used artificial lights, so we could not control the intensity of the irradiation. During our experiments about solar collectors we have developed a unit that is capable for measuring the functions of the efficiency. We have analysed two own-designed experimental solar collectors simultaneously, so with changing a parameter we could do comparison measurements. Beyond the determination of the function of the efficiency our studies cover the analysis of the transient effects and the properties of the serial and parallel connection. By the operating of the unit we have several observations which could be important informations during the designing of a control system for solar collectors.*
KEYWORDS: *solar collectors, comparison measurements, control system, efficiency*

INTRODUCTION

We have developed a unit for the measurement of the efficiency of solar collectors. During our study we have used our own-designed experimental solar collectors. The absorbers of the collectors have the typical tube systems: one of them is equipped with a single pipe (1), the other one has parallel pipes (2).

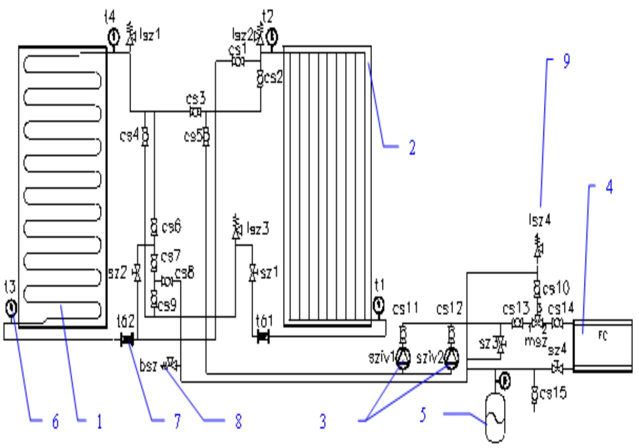

Figure 1. Experimental unit for the measurement of the efficiency of solar collectors
1 – solar collector with a single line pipe, 2 – solar collector with parallel pipes, 3 – circulation pumps, 4 – fan coil, 5 – expansion tank, 6 – thermometers, 7 – volume flow rate meters, 8 – safety pressure limiting valve, 9 – air-escape valve

The covering is removable, so we could study different polycarbonate sheets and the uncovered collectors as well. With the unit we can operate the collectors in parallel and in line connection. In case of in line connection we can change the order of the two collectors. We can lock out each of the collectors from the operation.

The efficiency of a solar collector is the function of the solar irradiation intensity and the temperature different between the collector and the ambient air. By the measurements we wanted to determinate the efficiency function as in a wide range as we can. We did the measurements in outdoor conditions, we have not used artificial lights, so we could not control the intensity of the irradiation. The other argument the temperature different between the collector and the ambient air in our system is well-controlled with the fan coil (4) which transfers the heat from the collectors to the ambient air. The number of revolution of the fan is continuously adjustable, and the cooling capacity can be further reduced by a valve and a bypass pipe. It is possible to lock out the fan coil from the circuit. With this construction we can change the temperature of the fluid at the intake of the collectors: as we reduce the cooling capacity the temperature increases. It supports the control of the temperature different between the collectors and the ambient air.

We have mounted two pumps, one of them controls the volume flow rate by the temperature of the fluid, and the other one is uncontrolled. The two pumps do not run simultaneously (3).

The volume flow rate meters (7) measure by displacement with rotary pistons. With this devices we can measure from 7,5 lh^{-1} which is an extremely low volume flow rate for the two collectors.

The accuracy is ± 2 %. The impulse relays mounted to the volume flow meters add impulses by liters. We have registered the impulses with a two-channel data logger.

We have measured the temperatures with K-type thermocouples and Testo 177-T4 data loggers. The accuracy is ± 0,3 °C.

Further the measuring points in the Figure 1 we have measured the temperature and humidity of the ambient air and by a Lambrecht 16131 pyranometer the intensity of the solar irradiation. The pyranometer is mounted between the collectors at the same plane. The response time our pyranometer is less than 18s, the accuracy is ±5 %, the non-linearity is less than ±1 %. The pyranometer conforms to ISO 9060 "First class" standard (www.lambrecht.net). The pyranometer used during the tests shall be placed in a typical test position and allowed to equilibrate for at least 30 min before data-taking commences. (ISO 9806-1).

During the measurements we have registered the values by 5 seconds. This rate enables the study of the transient effects.

SELECTING THE CLOUDLESS PERIODS

The momentary efficiency could be calculated only in sunny periods. In cloudy condition we can calculate average values for a term. In a diagram we can see the cloudy periods well, but because of the big amount of data we need to define a function to filter out the cloudy periods automatically.

The clouds make the intensity of the solar irradiation unstable. The response time of a solar collector is defined as the time taken for the temperature rise of the absorber plate to reach 90% of the final steady rise when the collector is subjected to a step change in the solar radiation level (N. E. Wijeysundera, 1976). The pyranometer senses the change of the intensity during less than 18 seconds. The mass - and so the thermal inertia - of the collectors is much higher than the pyranometer's, and the reaction is much slower. So during a period of a decreased irradiation that caused by a cloud rack the heat output of the collectors still high - caused by the higher irradiation of the previous minutes. If we calculate the momentary efficiency in this time, it will add wrong result. This error could be eliminated by two ways:

- *calculation of average efficiency for a longer period,*
- *filtering out the results of the cloudy periods.*

We have developed an algorithm for the filtering out of the cloudy periods. We have introduced this method in a scientific article (István Péter Szabó, Gábor Szabó, 2012).

CONNECTION IN LINE

Going ahead collector by collector the efficiency in serial connection is decreasing. Wrong control and too low volume flow rate result zero efficiency in the last collectors if the fluid reaches the maximum temperature before the output of the last collector. We have detected this effect in our unit and another solar collector system, too.

The second collector in line has a slower reaction to the changes of the weather (István Péter Szabó, Gábor Szabó, 2011).

EFFICIENCY DIAGRAMS

We can make the diagrams by queries from the database of the measurements. Figure 2 and Figure 3 represent the efficiency at 1000 Wm^{-2} solar irradiation in function of temperature difference between the collector and the ambient air.

With further queries we can define the function of the efficiency at different solar irradiation values for the two collectors (Figure 4, Figure 5).

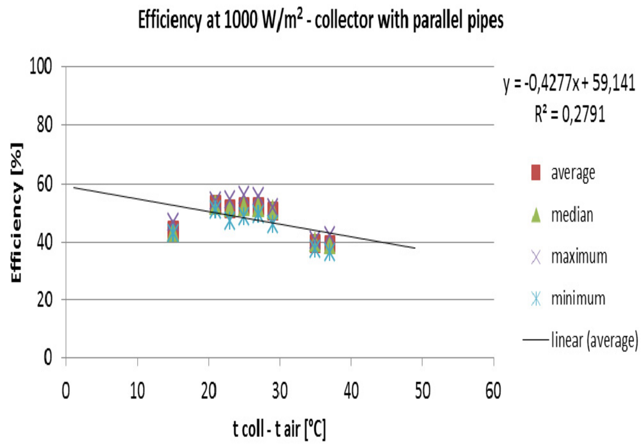

Figure 2. Function of the efficiency at 1000 Wm^{-2} - parallel pipes collector

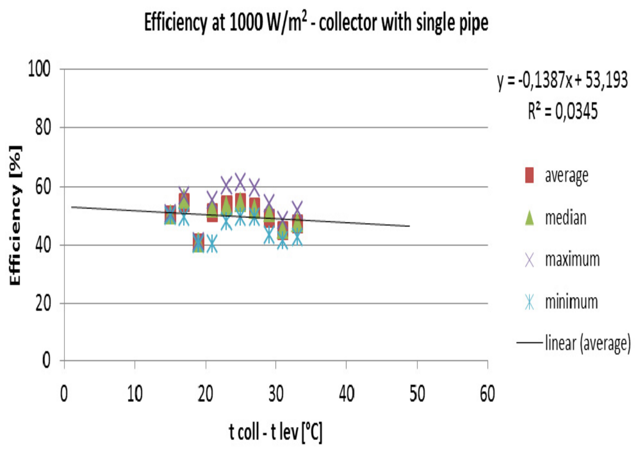

Figure 3. Function of the efficiency at 1000 Wm^{-2} - single pipe collector

We have used a tolerance of ± 1 °C for the temperature difference and ± 10 Wm^{-2} for the solar irradiation in every query. During a query at the chosen range of the temperature difference and intensity of solar irradiation we have hundreds of results with a deviation. The outliers mean measuring errors.

One of the filtering methods that most effectively diminished the outliers while retaining valid data was the removal of data where the global instrument's reading was less than 200 W (A. Lester et. al., 2006).

During the data process we also experienced that the low intensity of solar irradiation makes incorrect results, so we have removed this records from our database. By the ASHRAE standard the minimal intensity of the solar irradiation during the *measurements is 630 Wm^{-2} (ASHRAE, 1977). We also experienced that the deviation of the results starts to increase if the intensity of the solar irradiation is less than 600 Wm^{-2}.*

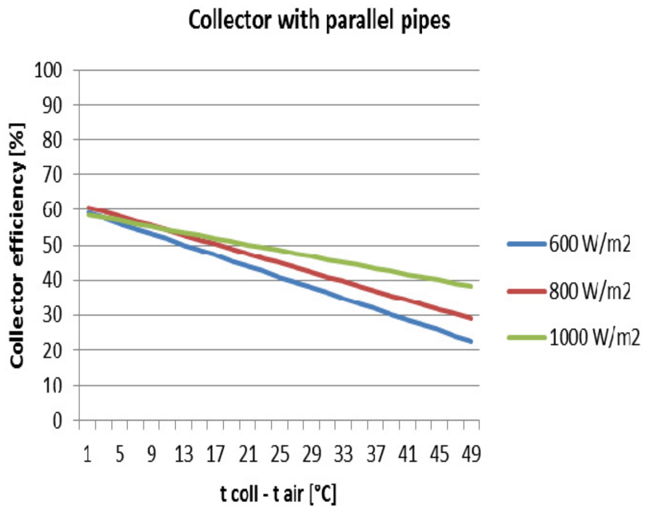

Figure 4. Functions of efficiency at different intensity of solar irradiation – parallel pipes collector

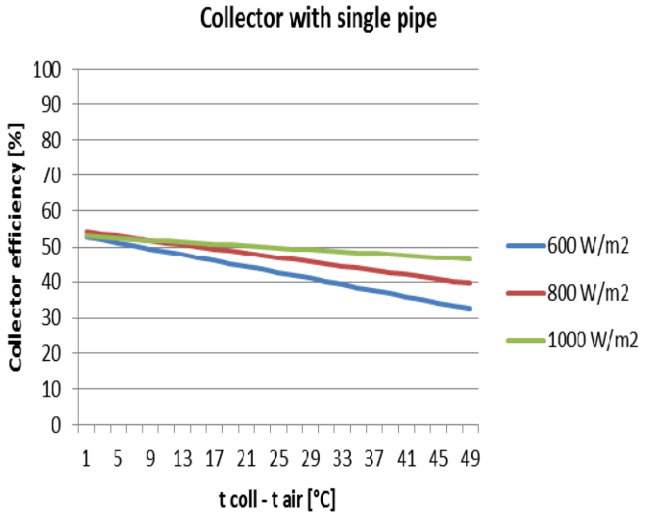

Figure 5. Functions of efficiency at different intensity of solar irradiation – single pipe collector

CONCLUSIONS

In our experiments we have developed a unit which is applicable for determining the function of efficiency of solar collectors with outdoor measurements. The calculated functions are well-fitted to the results and the characteristics are similar to the theoretical functions': increasing the temperature difference between the collectors and the ambient air the efficiency decreases, higher solar irradiation causes higher efficiency and at ambient temperature the efficiency is independent from the intensity of the solar irradiation: the maximum difference between the three intercepts is 2,36 % (parallel pipes collector) and 1,43 % (single pipes collector). The accurate fitting is representative in the range of 600÷1000 Wm^{-2} - from the solar intensity of the laboratory measurement to the minimal intensity specified by the ASHRAE standard.

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HUNGARY'S RENEWAL

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