Proceedings of the Seventh IASTED International Conference
POWER AND ENERGY SYSTEMS
August 29–31, 2007, Palma de Mallorca, Spain
ISBN Hardcopy: 978-0-88986-689-8 / CD: 978-0-88986-690-4

EXPERIMENTAL PERFORMANCE ANALYSIS FOR MINI PARABOLIC SOLAR REFLECTING COLLECTORS

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ABSTRACT
Mini – Parabolic solar reflecting collectors have been one of the main research topics due to their ability for possible integration into the building structure. A detailed experimental analysis of the thermal behavior of such a system suitable for installation on a roof, with tube absorber along to its optical focal lines is presented. The mini-parabolic collector system was placed at East - West orientation, and with an inclination of the parabola, so that the sun vector keeps at normal during a day. The fluid inlet and outlet temperatures in the absorber, the total solar radiation incident on the aperture surface, the ambient temperature and the fluid flow measurements were managed using a data logging system. The paper presents an experiment analysis of the results with a set of tube absorber diameters and fluid flows.

KEYWORDS
Concentrating systems, parabolic reflector, collector thermal performance.

1. Introduction

Many researchers have investigated the concentrating solar collectors systems of different sizes, scale and application type. These systems are capable to achieve big outlet temperatures at low cost prices, which implies high enthalpy. It is possible to use them in thermal – power plants, hot water production for district heating, and also solar air conditioning [1-6]. Particular interest is shown for roof integrated Compound Parabolic Collectors (C.P.C.). The research of such systems is under progress and only a few projects are monitored and reported [7, 8,9]. In order to increase the system performance roof integrated solar heating systems with glazed collector have been designed and investigated.[10] The target of this work is the experimental analysis of the efficiency of a special design and construction of mini parabolic reflecting collectors. (Fig. 1), [11,14,15].

The research focuses on the reliability of the performance and the optimization of the geometrical and physical characteristics as to maximize the output.

There is, also, an interest about the stability of the performance and especially on some parameters like, the constancy of flow rate, the accuracy in the parabola trough construction, which may appear during the experimental procedure. In addition, the paper discusses the innovation of the temperature controlled heating device, which allows for test experiments to be performed with T_{fin} steps increasing and followingly decreasing in preset values.

Experimental measurements of the system's performance have been carried out based on A.S.H.R.A.E. 93/97 standard. An automated electronic system (Fig. 2) to heat inlet water at predetermined temperatures was used. In this device, a data acquisition system (CR-1000 Data logger) to record all the needed quantities is also used. The experimental lay–out concerns measurements to determine the collector's thermal efficiency, under steady-state conditions, in various operating conditions.

Fig. 1 A mini parabolic system of 10 reflecting parabolas connected in series constructed in the R.E.S. Laboratory

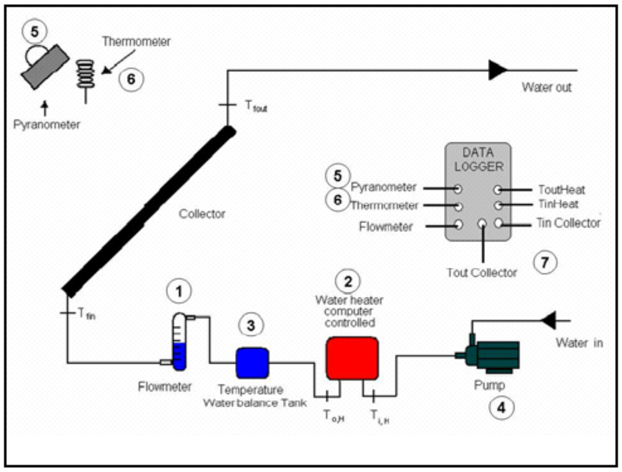

Fig. 2 Schematic representation of experimental device according to ASHRAE standard.

2. Experimental Lay-Out Description

Fig. 2 shows the experimental setup components:

1. Digital Flow meter output into the data logger
2. Programmed electric fluid heater temperature with on/off automatic switches.
3. Water temperature balance bowl
4. Fluid pump
5. Pyranometer installed on the collectors plane and its output into the data logger
6. Pt 100 thermometer for the measurement of ambient temperature, with its output into the data logger
7. Thermocouples for the measurement of collector's fluid inlet and outlet temperature with their outputs fed into the data logger

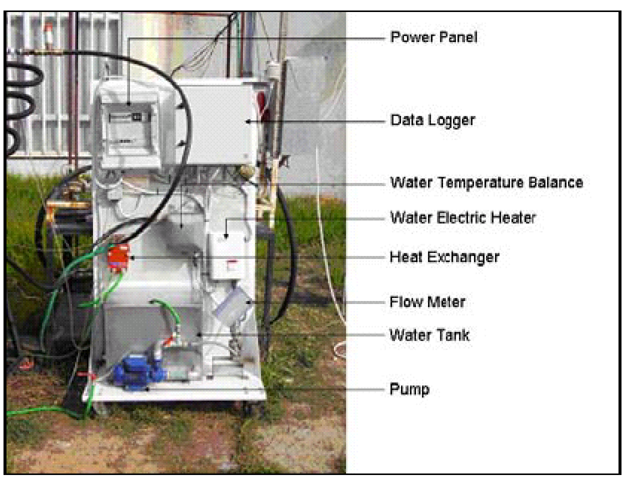

Fig. 3 Automation system of the experimental setup

The geometric characteristics of the system are summarized to follows:

- Length: L=1.25m
- Height: dp = 60mm
- Depth of the parabola: h = 50mm.
- Aperture of channel parabola:$2y_s$=100mm.
- Absorber tube diameter: Do= 22 and 15 mm.
- Concentration ratio: C = 1.45 and 2.12
- Focal distance: 12.5mm.

The reflectance, emissivity and the absorptance for the reflecting material and the absorber tube anodized Al and copper painted black respectively are:

- Parabola reflectance: $\rho = 0.90$
- Tube absorptance: $\alpha = 0.90$
- Parabola emissivity: $\varepsilon_q = 0.10$
- Tube emissivity: $\varepsilon_c = 0.80$

For the construction of the reflected parabola aluminum foils MIRO 27 – extra bright with special PVD coating from ALANOD Company, Germany, with thickness 0.5mm.

Because of the small thickness of the aluminium reflecting foil, in order to give to the foil the shape of trough parabola base and head parabola where used in both edges(Fig.4).

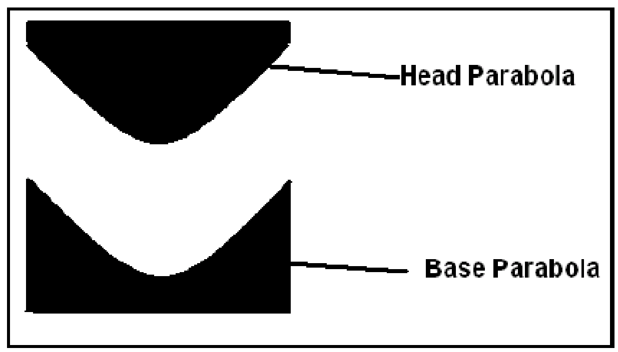

Fig. 4 Base and Head Parabola Constructed In C.N.C. Laboratory

3. Results

Here are presented the experimental results which consist of the fluid outlet temperature, T_{fout}, and thermal efficiency, η, of the parabolic solar collector for various values of mass flow rate, tube's diameter and fluid inlet temperature T_{fin}. The experiments were transacted during four days of October and November 2006. Figs. 5 and 6 give the solar radiation for the specific days and hours, the experiments were carried out. As it is obvious the solar radiation during the experiments remains almost constant.

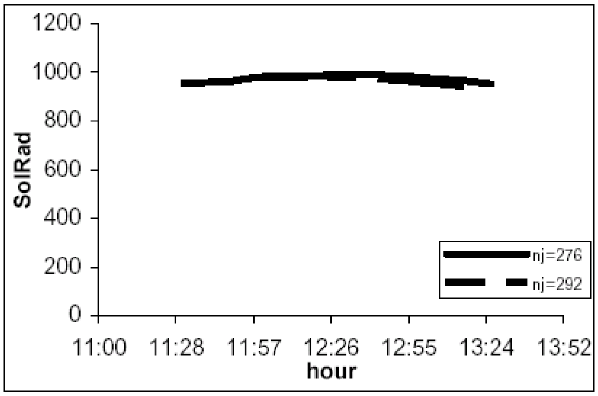

Fig. 5 Shows the solar radiation versus the solar hour for the case of 276 and 292 day.

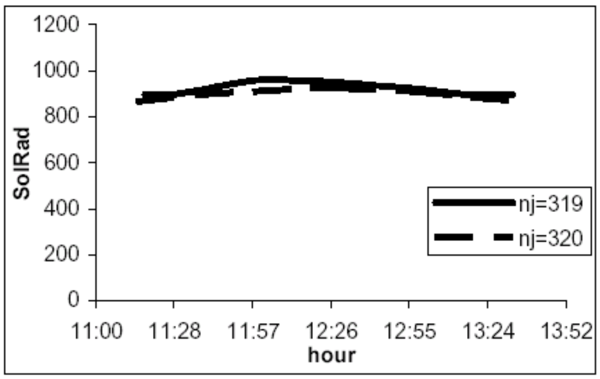

Fig. 6 Shows the solar radiation versus the solar hour for the case of 319 and 320 day.

The cases examined were for Patra city, in Greece. The collector inclination to horizontal was taken to secure that solar beam impinges normal to the aperture of the parabola during the experiments. The East–West (E-W) orientation was considered in all cases. The experiments were carried out for various values of mass flow rates and fluid inlet temperatures.

The instant values of solar radiation and ambient conditions, during the experiments, were obtained from sensors installed in the experimental setup.

Figs. 7 and 8 show the variation of fluid outlet temperature, T_{fout}, versus fluid inlet temperature, T_{fin}, for two different mass flow rates. As the mass flow rate increases the outlet temperature gets essentially lower for small values of inlet temperature, while as the fluid inlet temperature, T_{fin}, increases, the two curves tend to coincide. This behaviour is the same for both tube diameters D_0 = 15mm, (Fig. 7) and D_0 = 22mm, (Fig. 8). The phenomenon is more eminent in the case of tube diameter D_0 = 22mm, with the lower C value. It is, also, obvious that for both cases with absorber tube 15mm and 22mm, the curve with the higher value of mass flow rate gives lower T_{fout} results as it is foreseen, due to energy principles.

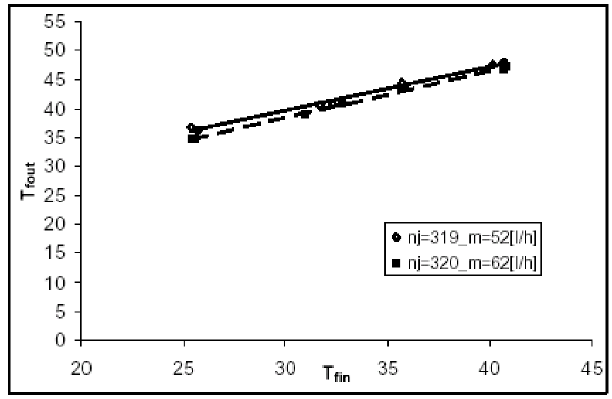

Fig.7 Outlet temperature versus inlet temperature for the case of parabolic collector with 15mm absorber tube.

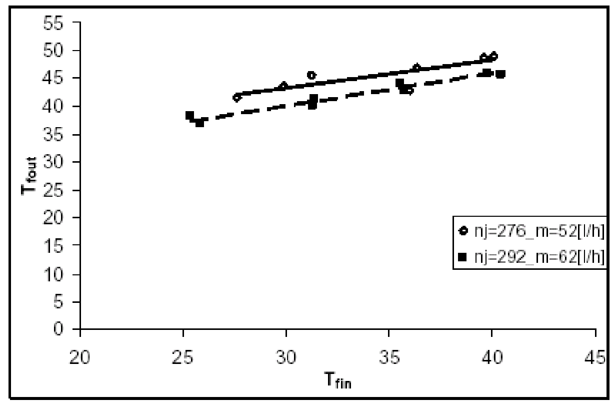

Fig.8 Outlet temperature versus inlet temperature for the case of parabolic collector with 22mm absorber tube.

Figs. 9 and 10 show the experimental thermal energy performance of the mini parabolic reflector system as a function of (T_{fin}-$T_{ambient}$), per unit solar intensity on the aperture. There were examined cases with various values of mass flow rate, for the case of 10 trough parabola with absorber tube 15mm and 22 mm respectively.

It is seem that system's efficiency increases as the mass flow rate increases for both cases. This is, also, expected as for high mass flow rate value the temperature in the tube absorber is kept low and therefore losses are decreased and efficiency, η, increased. Another result obtained from these figures is that for the case of 10 channel collector with 22 mm absorber tube, higher values of efficiency are obtained.

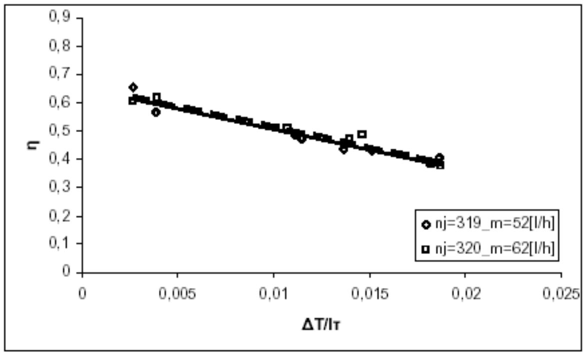

Fig. 9 Comparison between experimental results of thermal efficiency in various mass flow rate for the case of 10 channel parabolic collector with 15 mm absorber tube.

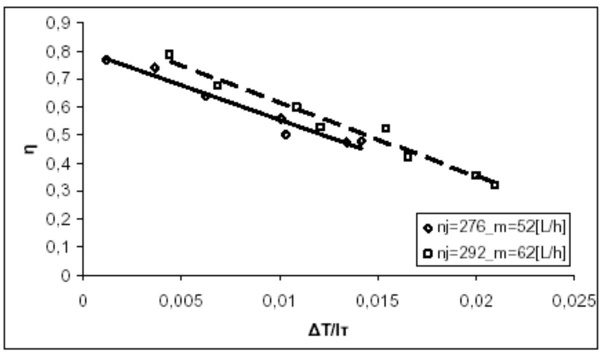

Fig.10 Comparison between experimental results of the thermal efficiency for the case of 10 channel parabolic collector with 22 mm absorber tube.

4. Conclusion

In the case of higher values of mass flow rates it is confirmed that the efficiency of trough collectors is higher.

The case of the curves in Fig. 9 is interpreted by the fact that C = 2.12 is higher than in the case of Fig. 10 where C =1.45 and therefore the temperatures are high enough not to be affected essentially by the small change in the mass flow rate. However this is not happened for the case of C = 1.45 (Fig. 10) where the influence is obvious and expected.

Several experiments required in order to investigate further thermal losses and thermal gain.

Experiments on energy performance of the parabolic collector were carried out in four characteristics days of October and November. The results obtained, provided the same energy performance profile of the system vs $\Delta T / I_T$ as outlined above.

Acknowledgments

The project is co – funded by the European Social Fund and national resources – (E.P.E.A.E.K. II) - **ARCHIMIDIS**

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