OPTIMISATION OF A LITHIUM BROMIDE (LiBr) ABSORPTION SOLAR COOLING SYSTEM

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ABSTRACT

The objective of this paper is to present the optimisation of the various components of a lithium bromide (LiBr) absorption solar cooling system such as the type, slope and area of solar collector and storage tank size. The collector types considered are the flat plate, compound parabolic and evacuated tube collectors. The optimisation is based on an energy benefit analysis, i.e., the amount of useful energy collected against the life cycle cost of the solar system. The system is modelled with the TRNSYS computer program using data for a typical meteorological year (TMY) for a hot climate (Nicosia, Cyprus) and a typical house with a total floor area of 196 m^2. The results indicate that for the present application the compound parabolic collector is the most cost effective whereas the optimum collector area is 15 m^2, the optimum slope of the collector is 30° and the storage tank size is 600 lt.

INTRODUCTION

Computer modelling of thermal systems presents many advantages the most important of which are the elimination of the expense of building prototypes, the optimisation of the system components, estimation of the amount of energy delivered from the system, prediction of temperature variations of the system and many other less important ones.

The complete solar system that is simulated, besides the absorption refrigerator consists of a number of solar collectors, a thermally insulated vertical storage tank, a conventional boiler and interconnecting piping. A schematic of the system showing also the simulation program information flow is shown in Figure 1.

The system was modelled with the TRNSYS simulation program [1] which consists of many subroutines that model subsystem components. The type number of every TRNSYS subroutine used to model each component is also shown in Figure 1 [2].

The solar system covers the energy needs of a typical Cypriot house which has a total floor area of 196 m^2 and consists of four equal size rooms [3]. The house load is minimised by considering an insulated roof, insulated walls, double glazed windows, internal shading and mechanically controlled ventilation (3 air changes per hour) in summer. The above construction requires an annual cooling load for keeping the house temperature at 25°C of 17,600 kWh with a peak load of 10.3 kW and an annual heating load for keeping the house temperature at 21°C of 3,530 kWh with a peak load of 5.5 kW.

The construction and type of the solar collectors is important and relevant to the operation and efficiency of the whole system. Flat plate (FP), compound parabolic collectors (CPC) and evacuated tube collectors (ETC), modelled with TRNSYS Type 1, have been considered in this study. The performance of the system

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employing these three types of collectors is investigated in order to select the most suitable for the present application. The final selection is made by considering the financial viability of the system.

Hot water is stored in a Type 38 tank. The vertical cylinder construction is made of copper and is thermally insulated with polyurethane. Also the tank is protected by a galvanised outer shell 0.6 mm thick. The backup boiler (Type 6) is assumed to have a maximum heating rate of 18 kW and a set upper temperature of 93°C. A number of thermostats (Type 2) are also used in order to control the flow to the solar panels and the operation of the boiler to keep the water temperature delivered to the absorption cooler always above 85°C.

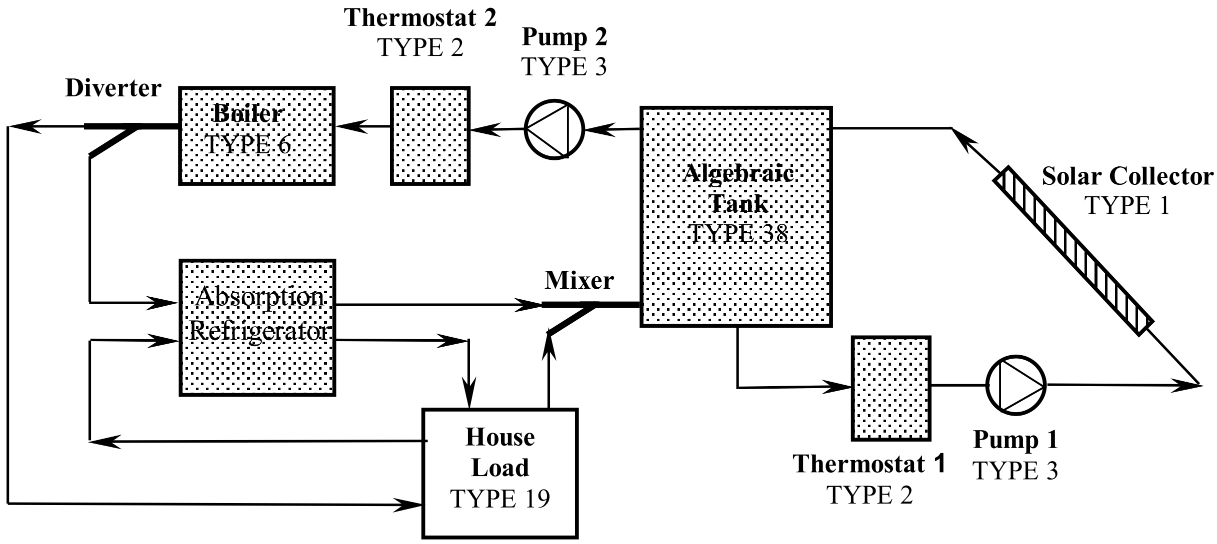

Figure 1: Circuit diagram and TRNSYS types used for modelling the system.

SYSTEM OPTIMISATION

A number of simulations were carried out in order to optimise the various factors affecting the performance of the system. The parameters considered are as follows:

a) *The collector slope angle*. The solar heat gain from the system for various collector slope angles is shown in Figure 2. As can be seen, the optimum angle in the Cyprus environment is:

   i. 25°-30° for the flat plate collector
   ii. 30° for the compound parabolic collector, and
   iii. 30° for the evacuated tube solar collector

This is due to the solar altitude angle, which for the latitude of Cyprus (35°) can reach to 78° during noon in June. Also, because of the load characteristics, with the total cooling loads being about 6 times bigger than the heating loads, the optimum angle should be such that the collectors are absorbing greater heat during summer.

b) *Storage tank size*. This factor also plays a role in the optimisation of the system. The boiler heat required by the system for different storage volumes is shown in Figure 3 for the three collector types. As can be seen, in all cases, a smaller tank size results in slightly less energy consumption by the boiler and slightly less energy collected by the solar collectors. It should be noted that the curves for the compound parabolic and evacuated tube collectors in Figure 3, for both the boiler heat and the collected heat, are so close that are indistinguishable.

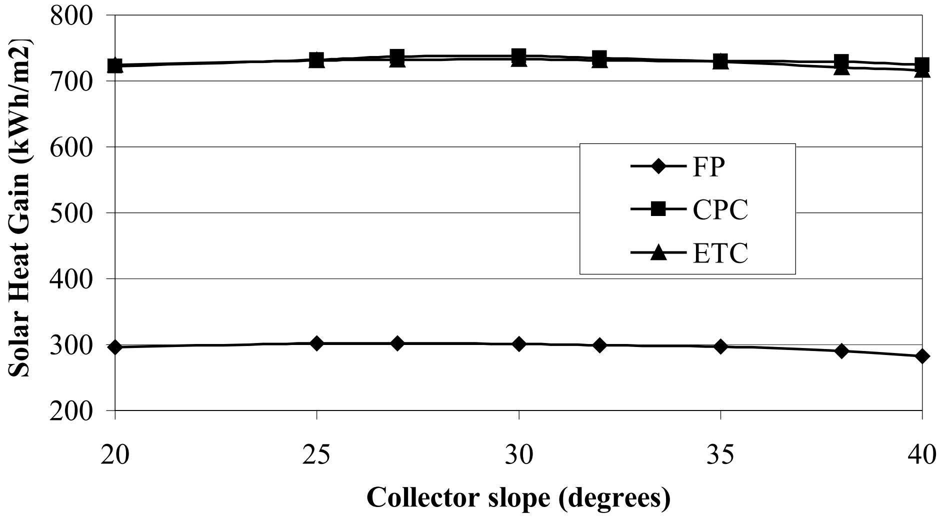

Figure 2: Effect of collector slope angle on solar energy gain.

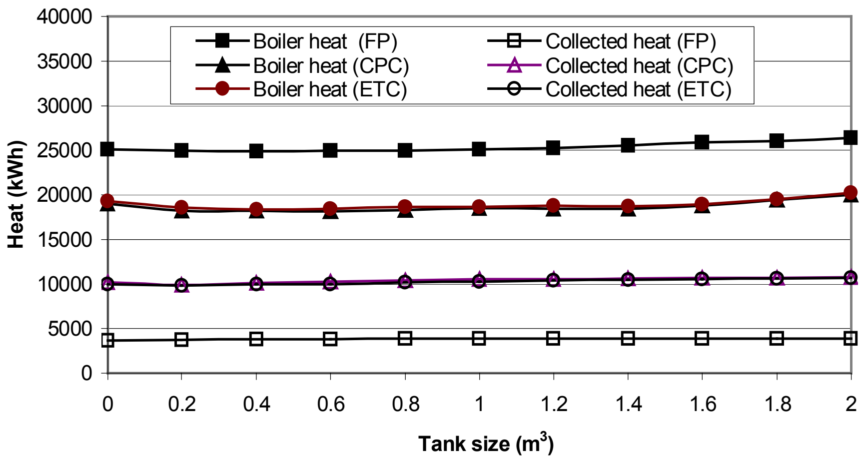

Figure 3: Effect of storage tank size on boiler heat required and collected heat for the three types of collectors.

The storage tank size is therefore decided only from the length of time intervals between firing the boiler. Between these intervals the tank should be able to supply the system with the needed water mass flow at the correct temperature in the summer. As can be seen in Figure 4, when the storage tank size is small the temperature in the cylinder cannot be kept above 85°C for long periods of time.

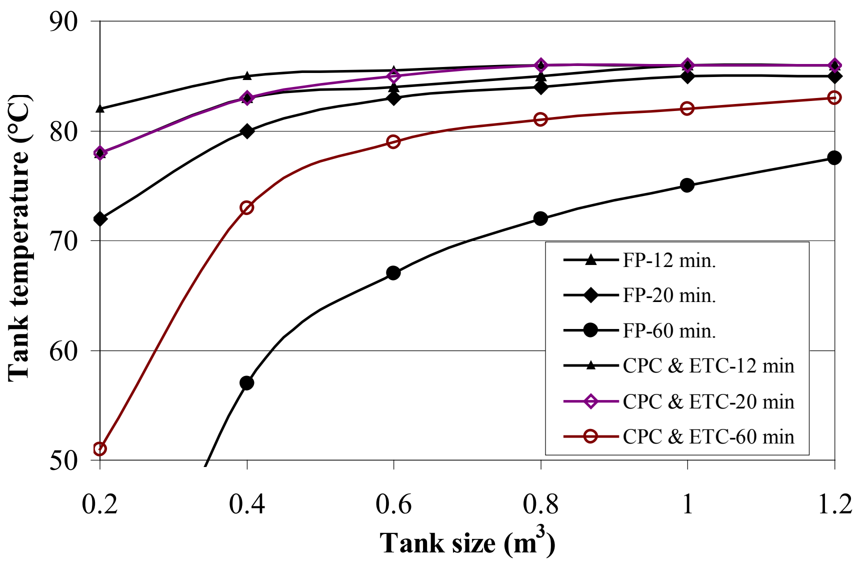

Figure 4: Effect of storage tank size on the boiler heat.

Assuming that the boiler is firing every 12 minutes, which may be a reasonable interval, the optimum storage tank size needed for the system would be:

i. 0.8 m^3 for the flat plate collector
ii. 0.6 m^3 for the compound parabolic collector, and
iii. 0.6 m^3 for the evacuated tube solar collector

Finally the effect of the collector area is evaluated against the boiler heat required. As it is expected the greater the collector area the less the boiler heat needed as indicated in Figure 5 and the more the collected heat as indicated in Figure 6.

To determine the optimum collector area the cost of the solar system must be compared against the fuel saved due to its use. The cost of the various types of collectors and the cost of the LiBr-water absorption cooler are shown in Table 1.

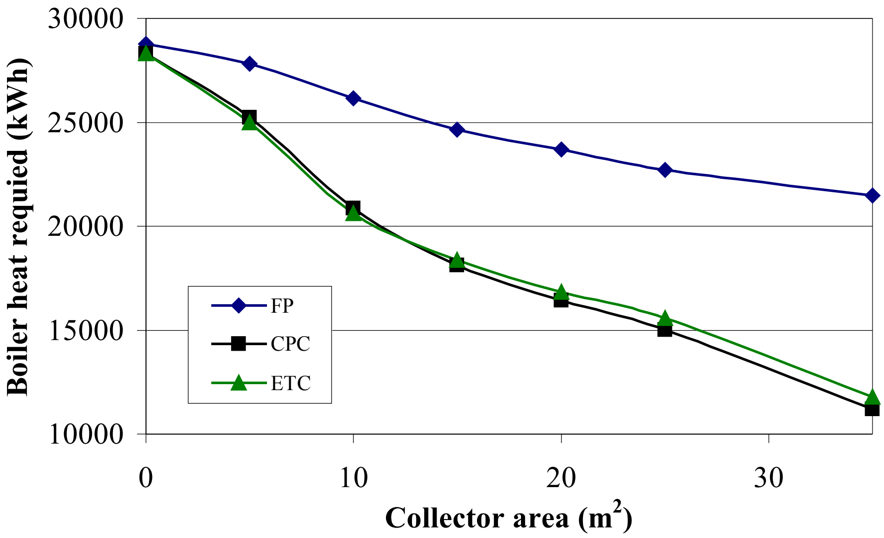

Figure 5: Effect of the collector area on the boiler heat required by the system.

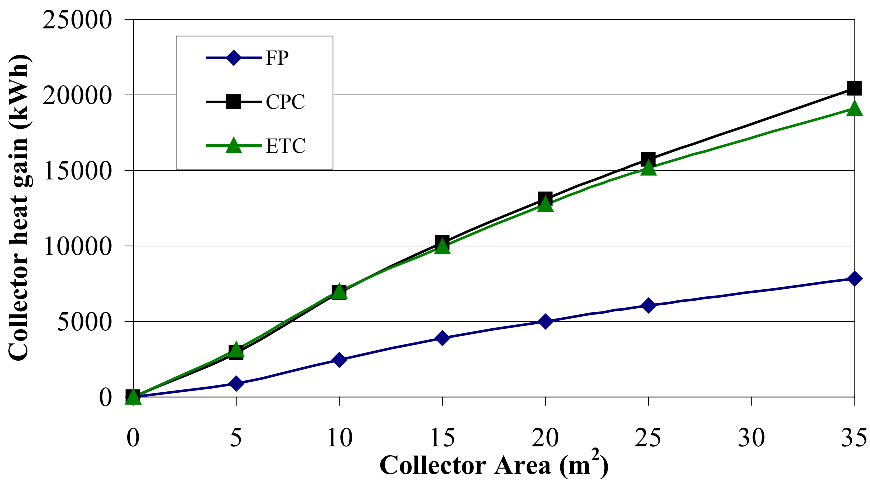

Figure 6: Effect of the collector area on the collector heat gain.

The economic method used, is the life cycle analysis (LCS) as outline in [4]. For solar systems:

System annual cost = Extra mortgage payment + Maintenance cost – Extra fuel savings – Extra electricity savings – Extra tax savings (1)

The scenario considered is that 30% of the initial cost of the system is paid at the beginning and the rest is paid in equal instalments in the next 10 years. The evaluation is based on the present price of the diesel, which is € 0.296 per lt.

TABLE 1.
COST OF SOLAR COLLECTORS AND ABSORPTION COOLER

Collector type	Cost
Flat plate collector Compound parabolic collector Evacuated tube collector	190 €/m^2 310 €/m^2 430 €/m^2
LiBr absorption cooler and accessories	8300 €

The results of the economic analysis are presented in Figure 7. As it is observed the only economically viable solution is to use the CPC with a collector area of 15 m^2. The flat plate collector and the evacuated tube collectors are not suitable for this application.

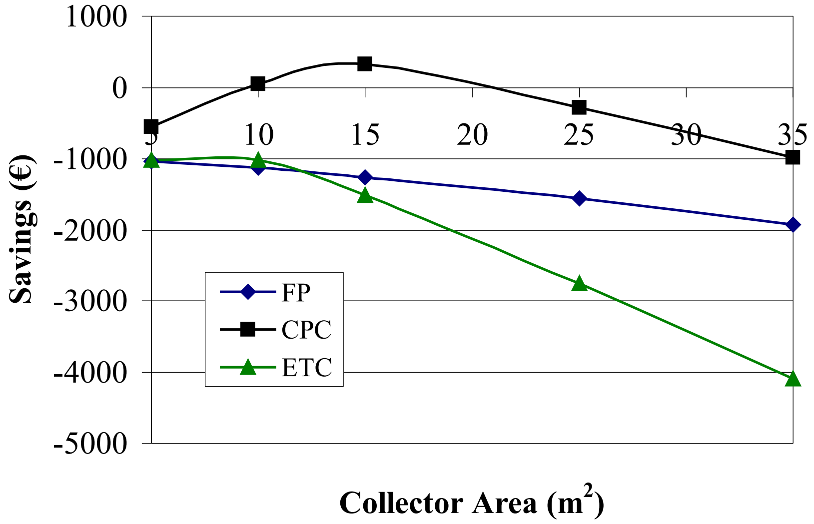

Figure 7: Collector area against LCS in € for a fuel price of 0.296 € / lt and a 20-year period.

Runs of the TRNSYS program for the optimum system have shown that from the annual building-cooling load of 17,600 kWh a total supply of 15,220 kWh is covered with boiler heat, supplemented by 8500 kWh of solar heat. The annual heating load of 3530 kWh is covered with a total supply of 2880 kWh of boiler heat and 1300 kWh of solar heat.

CONCLUSIONS

The final optimum system as obtained from the complete system simulations, consists of 15 m^2 compound parabolic collector tilted at 30° from horizontal and a 600 lt hot water storage tank. Although the fuel price considered is very low (0.296 €/lt) the system is viable only for the optimum case. This is due to the high price of the LiBr absorption unit. Details of the simulation parameters of the cooler are outlined in another paper presented in this conference.

REFERENCES

1. Klein *et al*. (1998). *TRNSYS manual*, University of Wisconsin.
2. Florides, G., Kalogirou, S., Tassou, S. and Wrobel, L. (2002). *Solar Energy*, **72,** 43.
3. Florides, G., Kalogirou, S., Tassou, S. and Wrobel, L. (2000). *Energy-The International Journal*, **25**, 915.
4. Kalogirou, S. (1996). *Proceedings of the World Renewable Energy Congress IV*, Denver, Colorado, USA, **2**, 1303.

