

# Performance Evaluation of Solar Flat Plate Collector under Climatic Conditions of Islamabad Pakistan

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## ABSTRACT

*Practical adsorption thermal refrigeration unit has been designed for the climatic conditions of Pakistan using Flat plate collector with activated carbon and methanol pair as adsorbent and refrigerant. This paper represents the collector performance in climatic conditions of Islamabad Pakistan with real time testing followed by a mathematical model. Real time data has been used in the mathematical model to evaluate the collector performance. In winter maximum collector temperature reached 68 Degree Celsius (154.4°F) in the month of December when ambient temperature was 7 degree Celsius (44.3°F) with maximum efficiency that is 44%. It can be anticipated from the given results that effectiveness of the collector will increase in summer season due to higher ambient temperatures.*

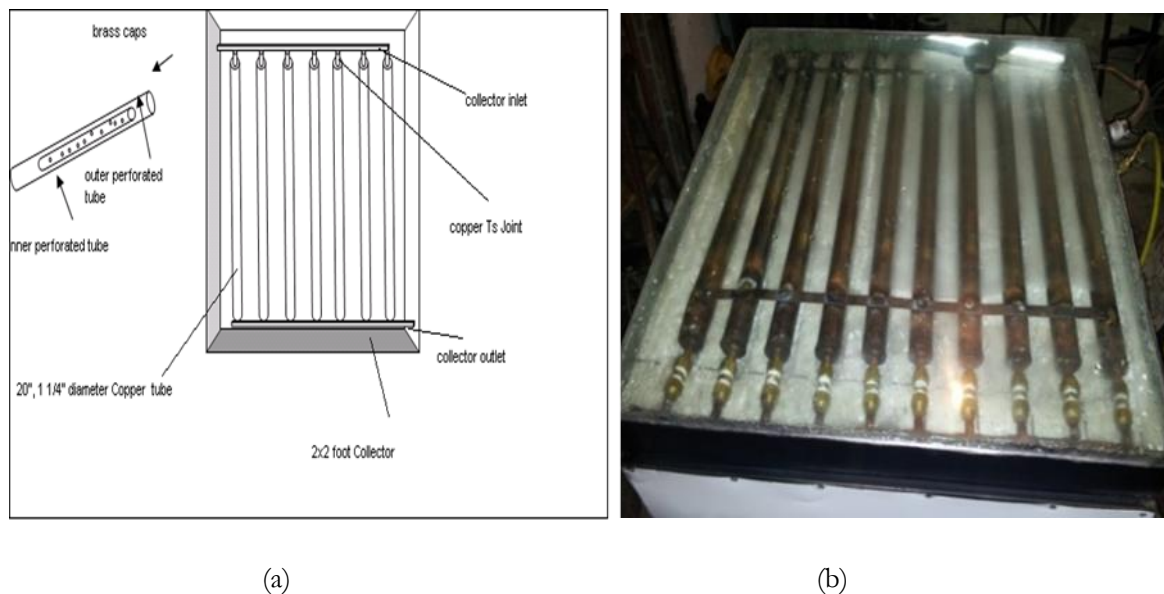
## INTRODUCTION

A practical designing, and Mathematical modelling of solar cooling and heating system have made it easier to design and predict the use and viability of machine in any area of the world. (Rifat A. Rauf et al. 2013) has performed a case study of solar adsorption thermal refrigeration system for the climate conditions of Dhaka a complete mathematical modelling and simulation of the system was carried out using silica gel and water pair as adsorbent and refrigerant. G santori et al. have carried out the simulation of the ice maker in the month of June for the climate condition of Messina the adsorbent and refrigerant pair used was activated carbon and Methanol. Whereas students of Michigan State university (Nabeel Aslam et al. 2009) tested the adsorption thermal refrigeration system using high intensity infrared bulb and assumed the climate conditions of guntenamo Africa. (F assilzadeh et al. 2005) has tested a system using brine salt as heat storing device for the climate conditions of Malaysia. Rekiyat Suleman et al has studied the behaviour of the solar collector using transits system with activated carbon and methanol pair under the climatic condition of Kano, Nigeria This paper provides the information about the performance of the solar adsorption thermal refrigeration system under the climate conditions of Pakistan the test was conducted in Islamabad in the month of December.

## DESIGN OF SOLAR COLLECTOR

Designed collector is flat plate type with inner perforated tube of diameter 0.35 inch (0.889 cm) fitted inside the outer tube having diameter of 1.5 inches (3.81 cm). The inner perforated tube is covered with steel net. Copper material has been used as a material for both tubes. Activated carbon that works as adsorbent material has been placed inside the larger diameter outer tube, adsorbed methanol gas will move through the passage of inner perforated tube. Resin for wrapping perforated tube with steel net is to make sure that only gas can move into the smaller tube instead of activated carbon.

The tubes are placed on thermo pole and insulator material easily available so that less heat must be lost during the process. This insulation has been placed at side and below the copper tube at the base of the collector. Black plate has been utilized at the surface of the collector to get maximum heat transfer to the adsorbent and methanol gas. Insulation material other than thermo pole can be utilized and maximum efficiency can be attained but reason to use thermo pole at this collector was because it is easily available in Pakistan at cheap rates.



**Figure 1** (a) Solar flat plate collector assembly (b) Practically designed solar flat plate collector at Islamabad Pakistan

## MATHEMATICAL MODEL OF COLLECTOR

To Calculate efficiency of the designed collector, mathematical model has been adopted by Fabio analysis of flat plate collector (Fabio 2008). Radiations that strikes the collector surface can be calculated using equation 1,

$$Q_i = I.A \quad (1)$$

Whenever sunrays strike the collector surface, not all are reached to the absorber material hence some are lost in the form of glass cover absorbing and some are reflected back, so the total heat intensity that strikes is product of the rate of the transmission of the cover and absorption rate of the absorber and given as

$$Q_i = I (\tau\alpha) \cdot A \quad (2)$$

Heat energy is also lost in atmosphere and is given as  $Q_o$ , it is dependent on the heat transfer coefficient rate, ambient temperature, temperature of the flat plate collector and absorption rate, and equation 3 shows the heat lost equation.

$$Q_i = U_L A \tau - T_a \quad (3)$$

Thus the rate of the useful energy  $Q_u$  is the combination of heat lost, the rate of the transmission of the cover and rate of the absorption.

$$Q_u = Q_i - Q_o = I \tau \alpha \cdot A - U_L A \tau - T_a \quad (4)$$

Useful heat of the collector can also be measured with the amount of heat carried away by the fluid that is methanol passed through it and given as,

$$Q_i = m a_p (T_o - T_i) \quad (5)$$

Using equation 5. Heat removal factor of the system can be found as given in equation (6).

$$FR = \frac{m_{cp} (T_o - T_i)}{A [I \tau \alpha - U_L (T_i - T_a)]} \quad (6)$$

Maximum useful energy gain can be found as;

$$Q_i = F_R A [I \tau \alpha - U_L (T_i - T_a)] \quad (7)$$

Hence the efficiency of the collector can be found according to the equation (8)

$$\eta = \frac{F_R A [I \tau \alpha - U_L (T_i - T_a)]}{AI} \quad (8)$$

## COLLECTOR TEMPERATURE

Since all variables like  $U_L$ ,  $F_R$ ,  $\tau \alpha$  are assumed to be constant in (Fabio 2008), the efficiency of the collector is measured using the formula with average solar radiation in Pakistan.

$$\eta = \frac{T_{IN} - T_{amb}}{I}$$

The inlet temperature is the collector inner temperature and outer temperature is the ambient temperature, whereas all the remaining variables are kept constant in this experiment. Below graph shows the efficiency of peak hours in winter from 11:00 am to 6:30 pm for the solar collector tested in Islamabad Pakistan. Below figure shows the

real time experimental test being conducted in Pakistan.

### FACTORS EFFECTING EFFICIENCY

Main Factors that effects efficiency of the collector are inlet temperature of the collector which mainly depends on the, absorber plate material and material used for insulation. These are the two key factors that affect the collector efficiency. On the other hand size of the copper tubes with area of the collector also plays significant role in collector efficiency. Below graph shows the collector temperature in the climatic conditions of Islamabad Pakistan. Whereas in figure 2 collector efficiency has been calculated which is almost same through the experiment that is nearly 44.8 % This efficiency can be significantly improved while using better insulation materials.

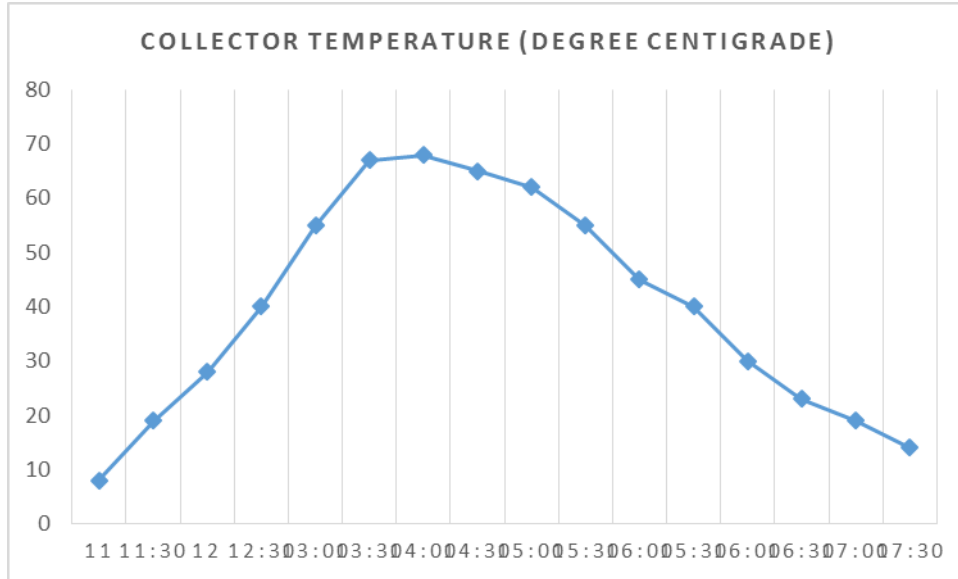


Figure 2 Collector temperature measured while testing

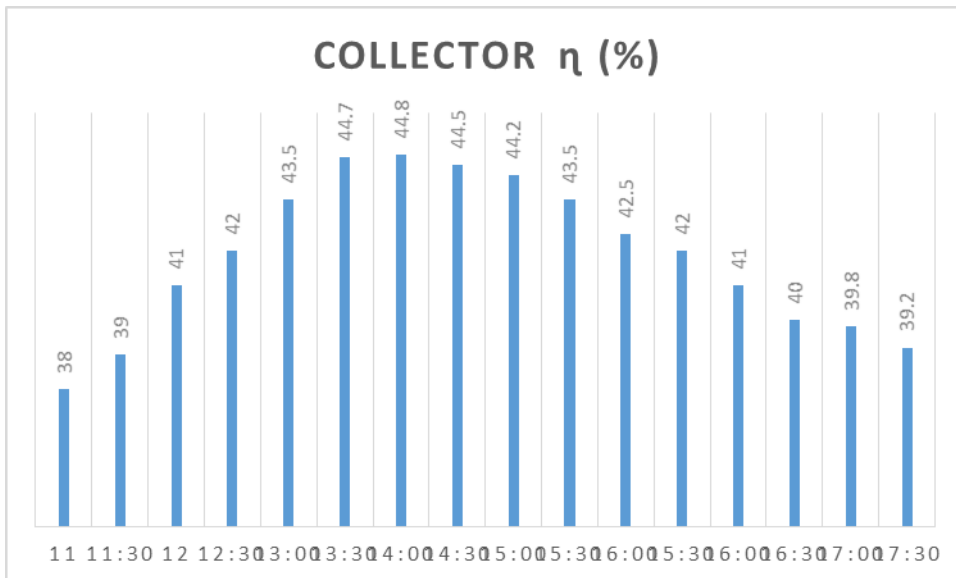


Figure 3 Measured Collector Efficiency

## COMPARISON WITH VACCINE REFRIGERATOR DEVELOPED IN MICHIGAN STATE UNIVERSITY USA

Results of the collector and complete refrigerator was compared with the one designed at Michigan State University, Reason for comparison with this refrigerator system was due to same adsorbent and refrigerant utilization in both cases on the other hand both systems were tested all day long. Below figure 4 and figure 6 shows the resemblance in data gathered while testing which shows positive results.

The difference between the collector designed at Pakistan and Michigan was in terms of construction of the flat plate collectors. The construction of the collector used in Michigan state university is different as they have used steel net where activated carbon was placed the collector was covered with black plate to gather more and more heat. Collector was tested using infrared bulb to resemble the hot environment of Africa. Collector design in Pakistan was tested under real climatic conditions and hence got real results of the complete test. Results of both refrigerator has been shown in figure 4 and 5 respectively. Figure show 6 refrigerators designed at Pakistan (a) and at Michigan (b)

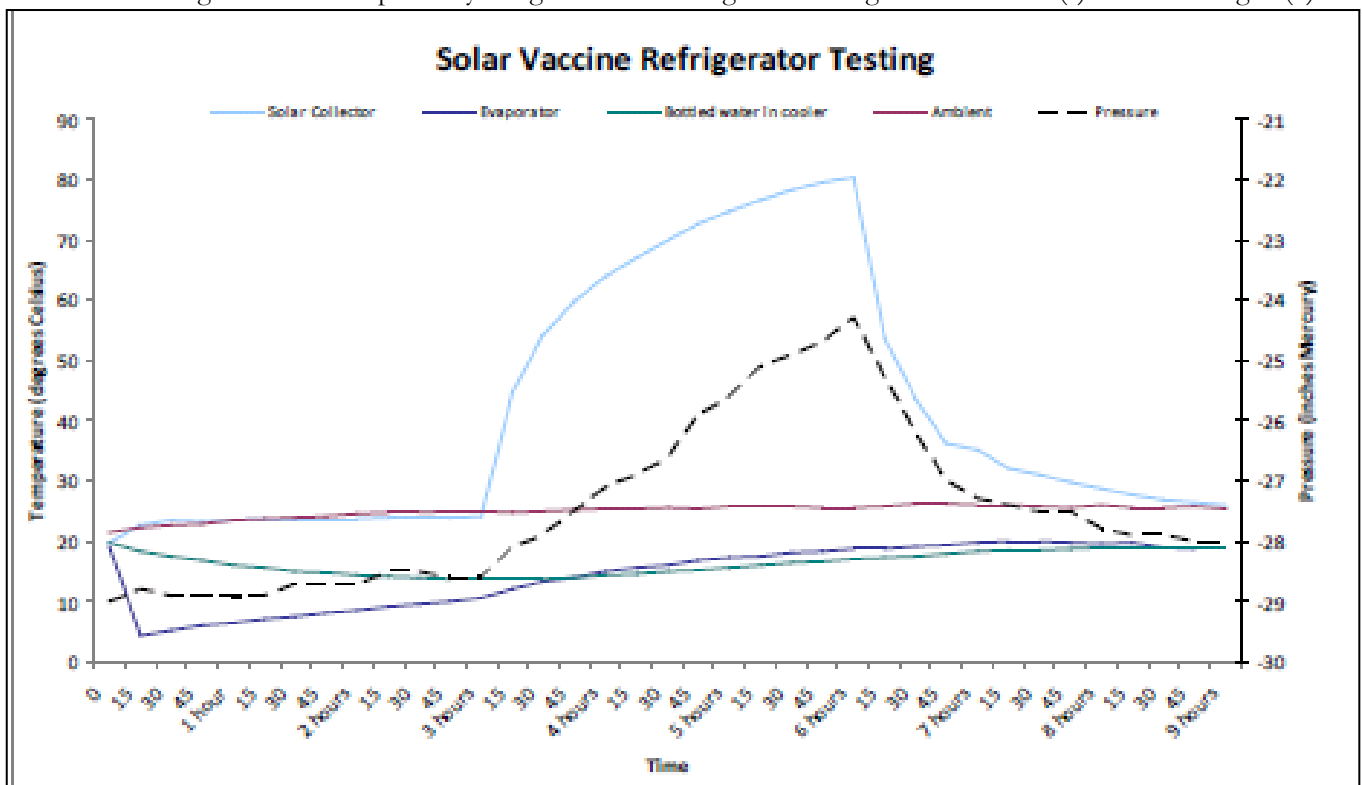


Figure 4. Refrigerator test readings for nine hour of Michigan State University [source: Vaccine refrigerator for developing Nations. (Manual) Michigan state university]

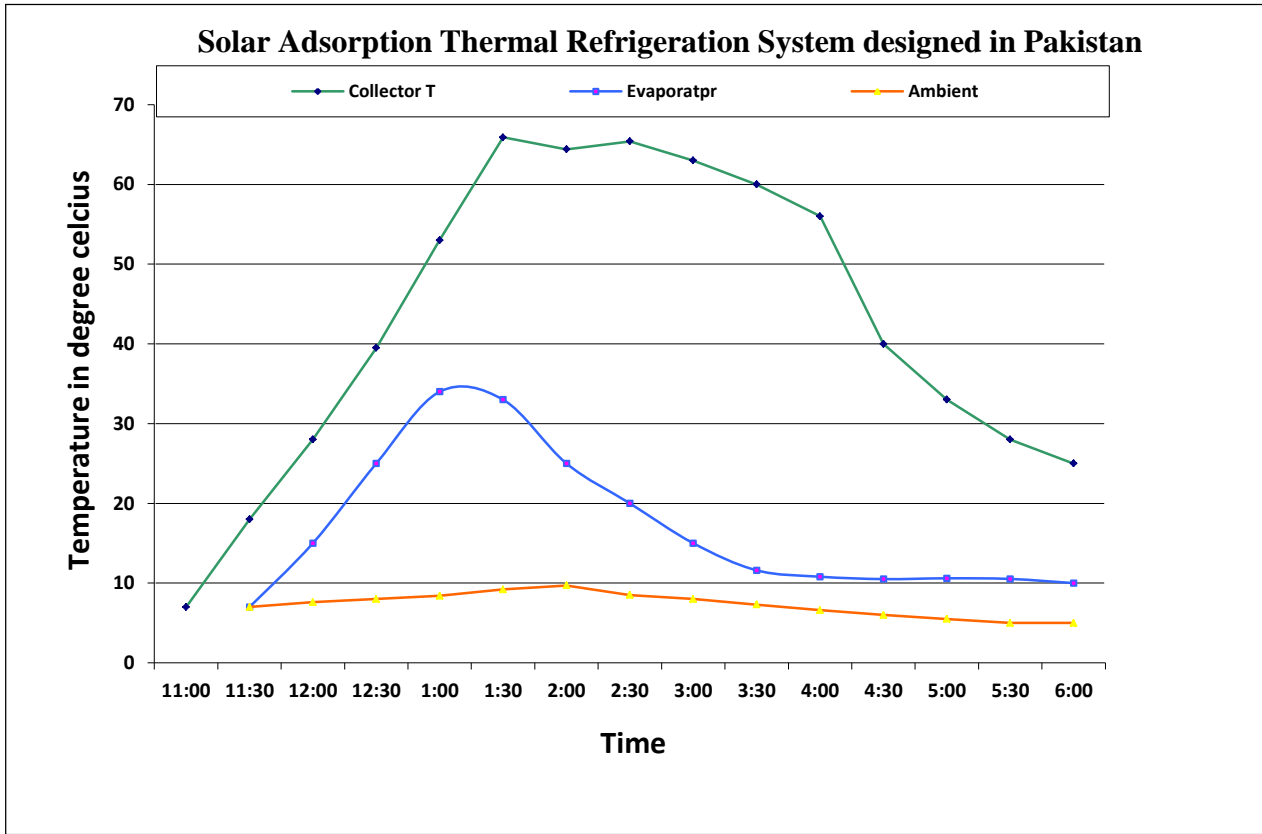


Figure 5 Seven hour test results of thermal refrigerator designed at Pakistan



(a)

(b)

**Figure 6** (a) Refrigerator designed at Pakistan (development phase) (b) Designed solar refrigerator at Michigan University (completely designed)

## CONCLUSION

Results extracted prove the viability of the collector in terms of availability of refrigerant, adsorbent, material for refrigerator assembly and climate conditions. Collector is completely manufactured locally and shows good results the impending research work will make it more mature technology increasing overall efficiency of the collector. Further work can be performed using the same collector including all constants in testing for more practical results.

## NOMENCLATURE

$A$	=	Collector area $m^2$
$F_R$	=	Collector Heat Removal Factor
$I$	=	Intensity of Solar radiation $W/m^2$
$T_C$	=	Collector Average temperature
$T_i$	=	Inlet fluid Temperature
$T_a$	=	Ambient Temperature
$U_L$	=	Collector overall Heat loss coefficient $W/m^2$
$Q_I$	=	Collector Heat Input $W$
$Q_U$	=	Useful Energy Gain
$Q_O$	=	Heat Loss

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