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Design and analysis of solar air heating system for room

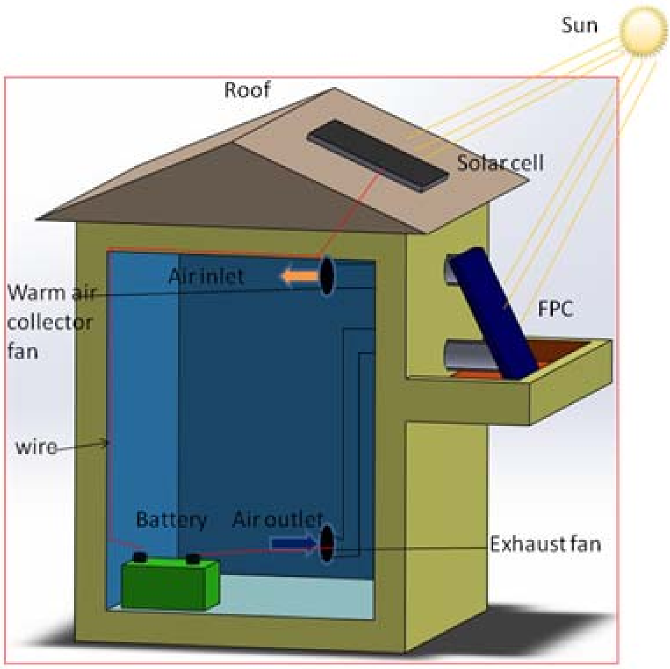
Sidra Dilshad[1*], Jafar Khan Kasi[1], Samiullah[1], Ajab Khan Kasi[1]

[1] *Department of Physics, University of Balochistan, Quetta*

HIGHLIGHTS

- Solar air heating system is designed to warm the room especially for cold climatic regions.
- Design low cost solar air heating system which would be easy to run.
- Maintenance free solar air heating system will be installed in the room which may run for many years.
- Solar air heating system takes energy from sun, which can reduce monthly home energy bills.
- Use of double glazing and insulation materials increases the efficiency of FPC.

GRAPHICAL ABSTRACT



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ABSTRACT

Humankind faces enormous challenges relating to energy supply and ecological safety. Heating system is an essential part of homes in colder area, which needs a lot of energy. In this work a solar air heating system is designed by using easily accessible materials to heat the room. The adoption of low cost materials and easy design represents the novelties of the proposed system as compare to the other commercial collectors. This eco-friendly solar air heating system consists of flat plate collector (FPC), battery, solar cell and fans. FPC consists of transparent glass, absorbing plate, insulating material and fluid (air). In this experiment flat plate collectors are used inclined vertically at the angle of 45° near to the wall of the room which gives attractive results. The results were obtained from south face located room. The time of solar heating is about 7-8 hours on the daily bases and an average temperature difference obtained was about 12°C as compared with the same dimension reference room. Experimental results conclude that this solar air heating system is able to heat the room in cold seasons. Hence the system making very important contribution for the saving of fossil fuels and diminution of carbon release on worldwide scale.

* Corresponding Author: sidrashazim57@gmail.com

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1. INTRODUCTION

Nowadays, heating is the most important issue facing by the population in cold areas. Due to increase in scientific advances, in population, in the sustainability of the built environment, and also due to the improved standard of living, demand of energy is increasing day by day and energy saving is becoming a major issue [1].To face the current threads in the world e.g. change in atmosphere, declining of fossil fuel sources, high cost of electricity and the incessant acceleration in the energy demand use of renewable energy and other energy sources are most sustainable ways. The renewable energy is most advantageous in hot and moderate parts of the world where the sun impose enormous quantities of energy on the surrounding which warms our homes and also reduce the use of fossil fuels [2]. Most inexpensive form of energy is solar energy which is accessible in developing countries located on both sides of equator and been looked as a source of infinite energy [3]. Solar radiations of little function will receive on the surface of earth due to reflection, absorption and scattering of the environment. For energy demand solar power is adequate in human society. The power that is intercepted by the earth is approximately 1.8 x 10^{11} MW, which is several times larger than the energy expenditure of current rate [4]. In many countries house zone utilization of energy is almost 30 -40% of the total energy expenditure. One fifth of the universe total vestige energy generation consumed by household cooling and heating individually, which means that our residence faces many ecological troubles like greenhouse emission. As a result we give a high ecological rate for our future. By examining more deeply building heating demand is about 60% of the total energy. Water heating or room heating is clarified for over 75 percent of energy use in individual or multifamily houses. More exclusively, in Europe the expenditure of energy in buildings is about 37%, and in United States energy expenditure of buildings is about 41% and for China 28% [5]. A large proportion of house zone is dependable on energy expenditure and greenhouse gas emissions. Therefore, an escalating number of managements have taken political actions to get better energy competence and to moderate carbon dioxide in houses. These trials mostly taken to encourage the innovative new energy devices to meet the hose zone energy demands more sustainably and also low in cost. Ventilating, air conditioning and heating systems are some major parts of energy expenditure and energy consumers in buildings. In effect, buildings total heat expenditure differs between 16% and 50% depending on buildings volume and environmental circumstances. These three systems are climate controls of the interior of house which adjust and control the temperature and humidity to provide thermal comfort and air quality inside the house. Solar air heating systems stores and collects the heat from sun, and maintains the heat within the house [6].

Solar collector is a device used to exchange the heat between the outlying sources. Radiations coming from the sun strike the collector absorber plate and then absorber plate collects the heat and transferred this collected heat towards the fluid [7]. There are two types of solar collectors. First one is concentrating and second one is non-concentrating solar collectors. There are further two types of non- concentrating solar collector, evacuated tube solar collector and FPC. The most common and most ancient type of collector is FPC. Hottel and his co-workers first time worked on FPC in 1942 and in 1958, respectively. They manufactured a FPC which consists of absorber plate, glazing, fluid (air or water), and insulating material. To enhance the efficiency of FPC, Tabor prepared choosy black surfaces in 1955 and after that many researches have been done to improve the thermal performance of the FPCs. FPCs catch the heat from the sun and this trapping heat can be used for many applications e.g. to heat the water, for house heating and also for many other industrialized applications. FPC performance can be drastically resolute by a resourceful photo thermal alteration of sun radiations into the thermal heat of the absorber plate of the collector. Due to this reason sun rays of wavelengths three hundred nanometer to twenty five hundred nanometers should be engrossed as far as feasible. For standard and low down applications of heating FPCs are very well-liked [8].

Many devices can be used to convert solar energy into thermal energy like solar thermal collectors, solar plates, solar photovoltaic/thermal (PV/T) collectors, Peltier modules, etc. These devices can be fitted near to the buildings or on to the buildings or sometimes can be incorporated into the building rudiments for example on roofs or on front walls of the buildings [9]. In summer months of the year, extra solar thermal energy can create heating stacks in residences and in other buildings and it is necessary to be eliminated by air conditioning but in winter seasons buildings required heating devices to maintain the thermal comfort inside the buildings [10]. In 2010, FPC was manufactured by Wazed and his co-workers and analyzed its working. They examined that flat plate solar air heater was working very well. They experimentally proved that flat plate solar air heater increased the room temperature about 45.5°C and the difference between this and ambient temperature was 12.25°C [11]. Another flat plate solar air heater was introduced by Chaichan and his co-workers they examined its performance in cold time of the year. They experimentally found that aluminum plate hotness raised about 142.45% as compared to the temperature of air stream. With the absorption of solar radiations the temperature of aluminum plate was 51°C and the ambient temperature was about 40°C [12]. A new installation of solar collectors has been installed by Motte et al., in 2013 which was unseen from the ground. It could be set up on new and old buildings. They calculated on the spot efficiency of collector according to the reduced high temperature and showed that the performance of these types of collectors were similar to the old type [13]. Vestlund and his co- workers commence a fascinating study concerning to the enhancement of the performance of FPC. They replace air with any other inert gas between the absorber plate and transparent cover. The benefit of using the gas in between the glass cover and absorber plate is reduced in the transfer rate of heat and also in moisture condensate. Other gases can also be used but inert gases are more striking and demonstrate better performance. For example CO_2 is an inexpensive gas and can be used in trim collectors but their performance was not so good. But the disadvantage of using the inert gases instead of air in the design will be more complicated [14].

Lot of papers have been written for building heating in the very last few decades and many type of solar air heating systems exists. Here, solar flat plate collector is designed for room heating. The present study is aimed to analyze the most important contributions of FPC to investigate the heat transfer enhancement techniques for room heating. At present time, there is no well-known record of intended FPC which acts as air heating system to heat the room. The design model is easy to process low cost and control system for temperature maintaining. Therefore, the primary inspiration in this research is to formulate a first foray into this territory.

2. EXPEREMENTAL WORK

The solar air heating system was designed by using easily accessible materials in the market during the year of 2019. The designed solar air heating system is very easy to construct to heat the room. The solar air heating system consists of FPC, battery, solar cell, warm air collecting fan, exhaust fan and thermometers. Figure 1 shows the block diagram of the system.

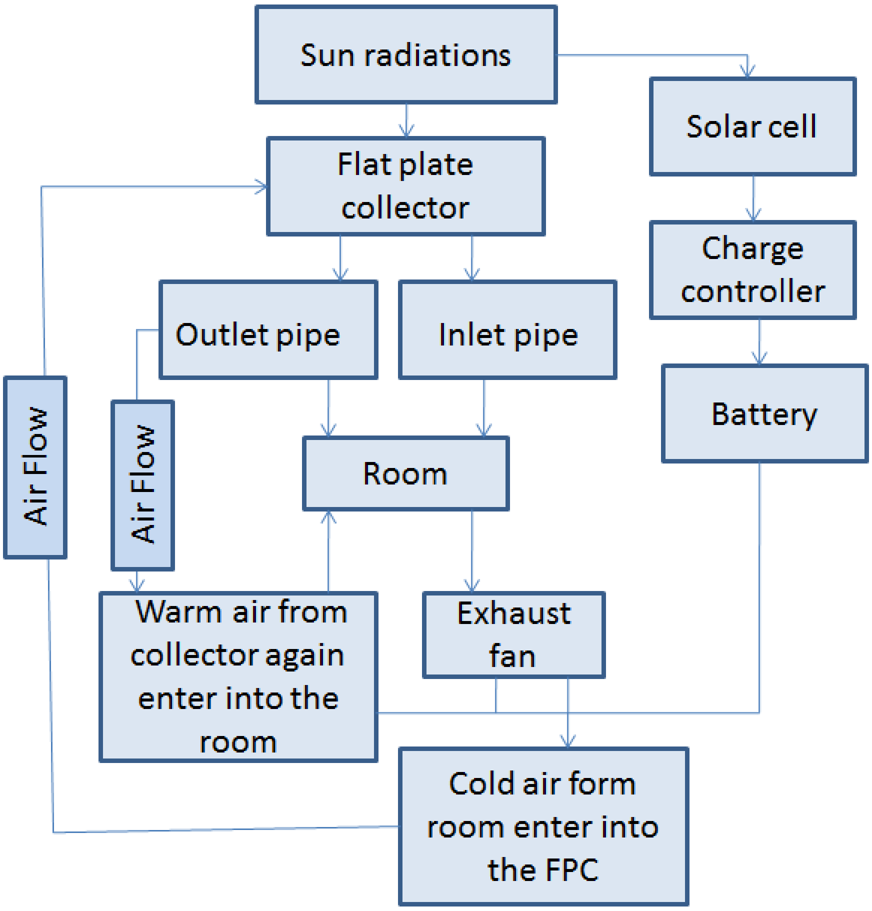

Fig.1. *Block diagram of solar air heating system*

The system is designed in such a way that the sun radiations can easily trap and increase the temperature of air. The room used for heating purpose was south faced with dimensions of 1000 ft^3 (10ft x10ftx 10ft) named as system room. Another same dimension room was considered as reference room. To compare the temperature of both system and reference room, two set of experimental data was obtained. Figure 2 shows the schematic diagram of the system.

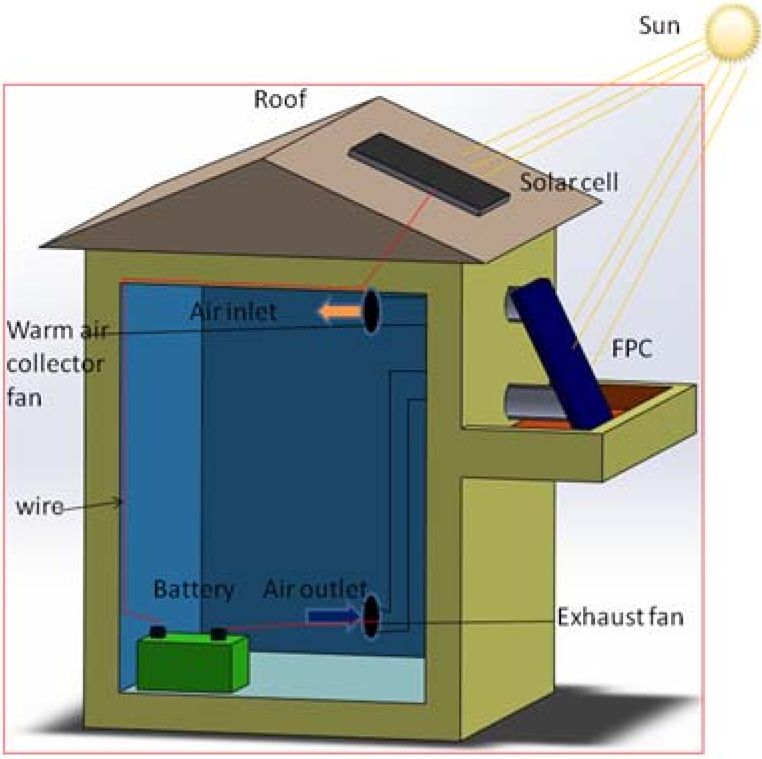

Fig.2. *Schematic diagram of solar air heating system*

2.1. Manufacturing of FPC

FPC gathers the sun's energy, transforms its radiations into heat and subsequently transfers into fluid. To increase the temperature of the room two FPCs were made, which consist of glazing, absorbing plate, fluid (air), and insulating materials. The absorbing plate of collector was painted with a wavelength selective black color which increases the absorption of sun radiation spectrum of ultra-violet and at the same time it decreases heat losses in the infrared spectrum. Absorbing plate has two headers and five risers. Styrofoam was also fixed behind the absorber to control heat losing and then sealed the glass (glazing) by silicone and metal screws. The glazing allowed the radiations to transmit from it and enters in the collector. As compare to plastic, low-cost glass is preferred to cover the material because it has low transmittance to infrared radiation and stability and high transmittance to visible light. To avoid heat losses due to convection and conduction double glazing was used in the experiment. By controlling these heat losses, fluid can absorb more thermal energy which increases the efficiency of FPC. Wood, saw dust and foam was used as insulating materials in FPC. Flat plate collector was mounted on the terrace of the system room. Parameters of FPC are given in table 1.

Table 1. *Parameters of flat plate collector*

Length of FPC	45.5 inches
Width of FPC	26.5 inches
Diameter of header	1.25 inches
Diameter of riser	0.75 inches
Distance between Plates	9 inches
Distance between inlet and exhaust	10.2 inches
Distance between outlet and exhaust	48 inches
Number of headers	2
Number of riser	5
Distance between two riser	5 inches
Distance between header	48 inches
Distance between edge and riser	2 inches
Distance between edge and header	2.5 inches

Later on the connection of both collectors were connected with each other and then placed on the stand. Stand is placed at an appropriate angle with floor as shown in Fig.3.

Fig.3.*Experimental setup of FPC*

2.2. Air Circulation System

For proper warm air circulation, inlet and outlet pipes from FPC are entered inside the system room. Inlet of the room is the outlet of FPC and outlet of the room is the inlet of FPC and vice versa. An exhaust fan was installed on inlet pipe of FPC which takes the air from the room. This air is then passed through FPC and the heated air is entered back to the room through the outlet pipe as shown in the Fig.4.

Fig.4. *Heating system in room, on left warm air entering into room from collector while on right cold air exhausts from room entering into collector.*

Solar panel has been used in the system to run the fans. Solar panel absorbs the energy from sun and converts this energy into electrical energy. Solar plate was mounted on the roof of the system room. A charge controller was used to control the overcharging of battery. Five thermometers were used in this experiment, first one is placed at inlet pipe, 2nd one is at out let pipe, 3rd one is placed in system room, 4thone is placed in reference room and last one is used to measure the ambient temperature.

3. RESULTS AND DISCUSSION

This study shows the results at different times of solar air heating system and also shows the comparison between the same dimensions reference room with system room. The graphs show the temperature variations after every 30 minutes of exhaust fan, warm air collector fan, system room, reference room, and ambient air during daylight for the months of March, April and May 2019 as shown in Fig. 5, Fig.6 and Fig.7 respectively. The data was taken between 8:00 am to 6:00 pm. In the start of the day about 8:00am there was minor difference (about 1-2°C) between system room temperature and reference room temperature. The temperature values of air inside the FPC gradually increases from 8:30am till 2:00pm and remains constant at about 3:00pm and then decrease slowly. It is mainly due to the blowing of air of the atmosphere. At about 6:00pm temperature remains almost same as of the temperature of the start of the day. In sunshine hours the variations in temperature is due to the incessant in sun radiations during the morning until it attains its peak values at midday and after this starts to decline till the end of the day. The graphs clearly indicate that the temperature difference between system room and reference room was about 12°C which show the system performance. Warm air maximum temperature (at about 2:00pm) of FPC reaches to 50°C, 52°C and 59°C in clear (sunny) days in the months of March, April and May respectively. In FPC, plate absorbs the sun radiations and then transfers this energy in to the working fluid (air).Thus the temperature of working fluid (air) in FPC is directly proportional to the incident sun radiations. The temperature variations in the cloudy or rainy days are expected due to the existence of dust accumulation and shadows of the clouds. However the rainfall and cloudy day rate of Quetta is very low.

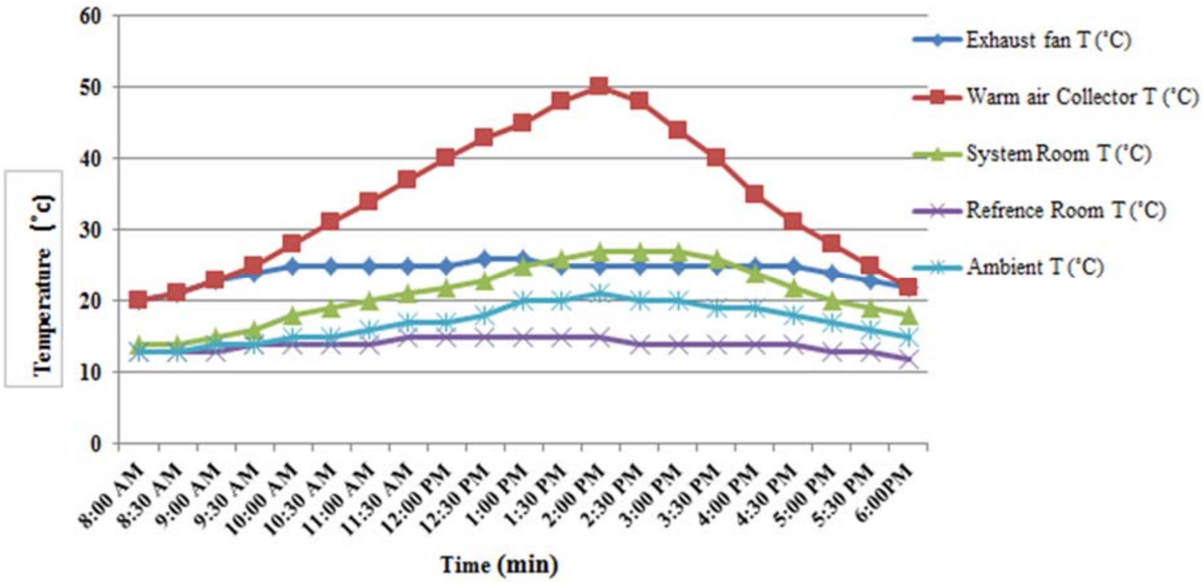

Fig.5. *Results for the month of March*

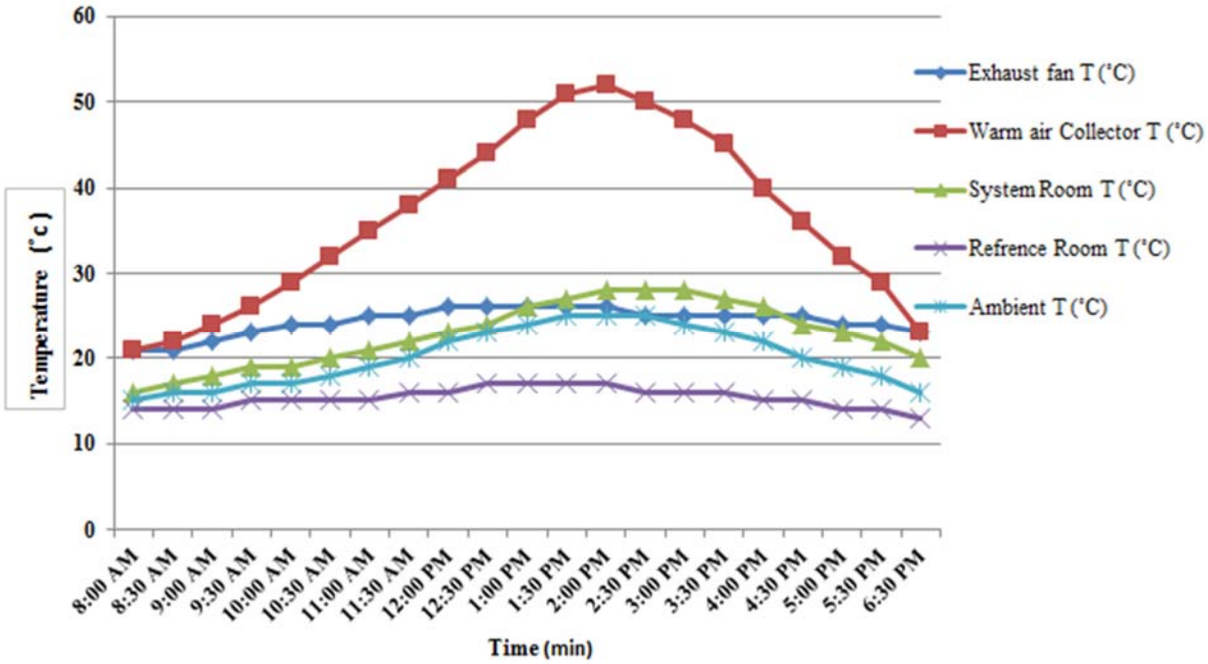

Fig.6.*Results for the month of the April*

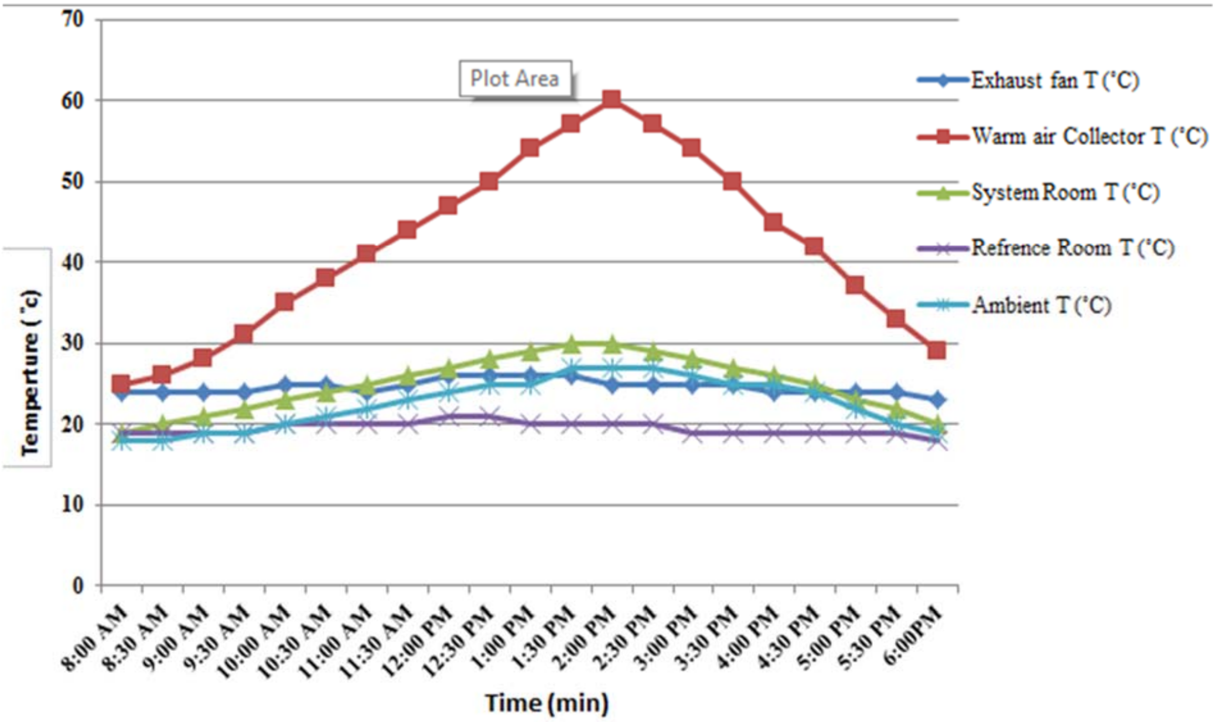

Fig.7. *Results for the month of May*

4. CONCLUSIONS

Theoretical and experimental studies were performed to assess the thermal performance of solar air heating system to heat the room by featuring the perforating absorbing flat plate collector under the weather conditions of Quetta. This experiment results clearly shows that for heating purpose of room the use of this type of collector is possible in winter conditions. The variations in the temperatures of system room and reference room was about 12°C and the fluid inside the FPC reaches the maximum value of about 59°C which shows its good performance. Moreover, the FPC is capable to meet our heating demands during cold months. The benefits of using FPC are that it is cost effective and easy to install near to the wall of the rooms.

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