Practical Investigation of Effectiveness of Direct Solar-Powered Air Heater

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Abstract—*Solar energy is clean and available, and its use doesn't hurt the environment. Heating conditioned homes and offices in wintertime deduct a large part of the amount of fuel consumed for these purposes. The use of solar radiation to heat the air proved its feasibility and usefulness and is in the research and development process and takes many forms. One of the primary types of solar air heaters is solar air heater of a transparent collector.*

In this study, a transparent collector solar air heater was designed and manufactured with an area of 1 m2. An aluminum plate was used to be the heating source; it takes its heat from the solar radiation. The tests results confirm the validity of this solar air heater type. The temperature of the heated air increased about 101% of the ambient air. The aluminum plate has proven to work as a source of heat.

Keywords—Air heater, solar radiation, solar air temperature, transparent collector

I. INTRODUCTION

Air and water heating is the primary consumer of energy in buildings in the cold country. Recent studies about the disbursements of energy in housing in the United States showed that heating consumes up to 42 % of the energy while in commercial buildings it takes up to 36% [1, 2]. Natural gas is the most widely used for heating in the whole United States as a fuel. However; some parts of the country are using other types of fossil fuels such as heating oil and propane on a large scale [3]. The result burning these types of fossil fuels is the enormous emissions of the greenhouse. For example, in 2010, the fuel used to warm housing in the United States emitted the amount of 324 million metric tons of carbon dioxide emissions [4].

The heating and cooling using renewable energy (REHC) have been described as the "Sleeping Giant" because of the enormous potential of renewable energy globally. The use of solar energy, biomass, and geothermal resources currently available, cost-effective, and can reduce a significant portion of the carbon dioxide emissions resulting from the burning of fossil fuel [5]. The renewable heating techniques work in the same way as traditional heating systems to a large extent, except that it uses renewable energy to generate heat instead of fossil fuels such as natural gas and oil. The renewable heating technologies can't replace the fossil fuels heating systems completely, but instead of using a conventional heating system all the time, it can become a spare system for the renewable resources when heating it becomes not sufficient to meet the heating needs. The heating systems requirements depend on the size and complexity of the required air conditioned spaces [6].

It must be taken into consideration when designing a heating system operates by renewable heating technologies as it provides some heat intermittently while the remaining part must be provided by fossil fuels, no matter what time of day or season. The renewable heating technologies cannot always be a substitute for the existing heating systems now, but it complements it. Therefore, it is economically desirable to design the renewable heating system to reduce fossil fuel disbursements. Also, it is preferable to design it to be used for pre-heating the air to minimize the size of the unit that operates on conventional fuel, besides, to reduce the fuel consumption costs [7, 8].

Renewable heating technologies became widely used worldwide, as flat panel and the solar collectors who work by vacuumed pipes. These techniques are subjected to developments, and its use depends on the availability of sufficient space to install solar collectors. The primary constraints that need to be researched and developed for the solar heating technologies are the limits of the working temperature (Fig. 1), and the availability of sunlight according to time (as it is in the peak values at noon) compared to the need. As sometimes, the amount of collected heat gathers more heating energy than the required and causes excessive heating of the conditioned space [9]. Fig. 1 shows the heating applications techniques and the expected temperature range of the heat transfer fluid within the renewable heating system. The degree of fluid heat carrier is not necessarily the same as the final temperature of the hot air, which eventually enter into the air conditioned space [10].

Another technique relies on directly air solar-powered heating can be used, using a transparent collector. After the air passes through this collector and heated, it is forced to enter through the air ducts of the ventilation system to the heat the desired space. The transparent solar collector can collect approximately about 60-70 % of the solar energy that reaches the collector face, which makes this type of alternative heating techniques a very effective in providing heat during the days with low temperatures. This method is suitable for housing, which has walls facing south [11].

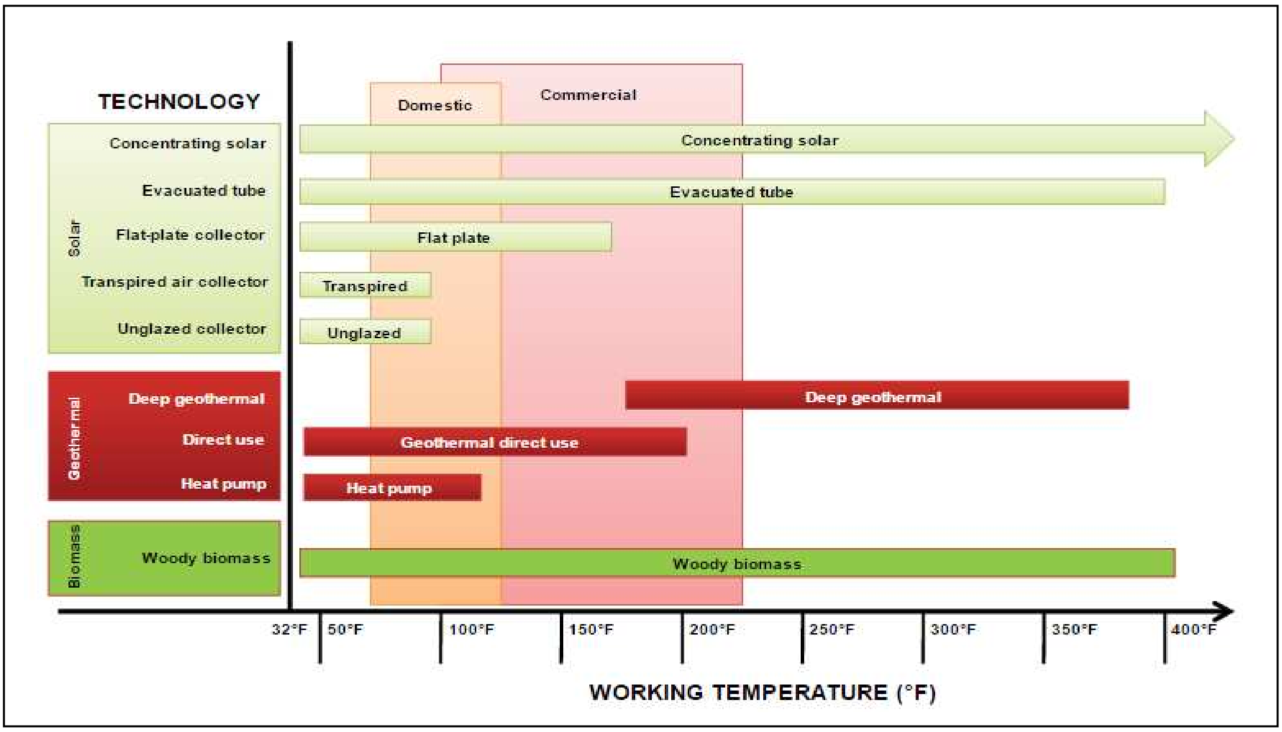

Fig.1: The limits of the working temperature of the solar heating technologies

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Fig. 2 represents a diagram of the air heating solar collector [12]. The transparent solar air collector contains a metallic material dyed in non-shiny black color. This collector fixes on a wall overlooking to the south side of the building. The fan withdraws the outside air through holes in the solar collector wall and passes it on the metal plate where the air is heated to temperatures of up to 10 to 55ºC higher than the ambient air temperature depending on the intensity of solar radiation and the time of day. The air heating by transparent solar collector technology remains an emerging technique in the field of solar heating. It is expected that this type of technology to become the best applications of hot air and ventilate the interior spaces. This technique can also be used in several manufacturing industries and agriculture such as crop drying [13, 14].

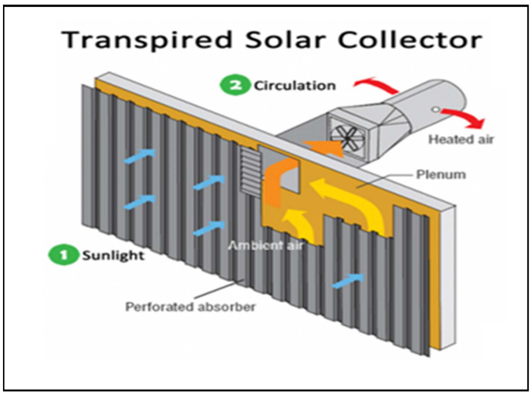

Fig.2: A diagram of the air heating solar collector

Iraq is located close to the Sunbelt. Therefore, most months of the year is hot in most of the regions. The winter months are two only in December and January. Most of the houses in Iraq are heated using liquefied petroleum gas and kerosene, which yields horrible emissions and cause high health risks.

In this study, the aim is to test the transparent solar collector work in the winter of the Iraq capital city of Baghdad conditions. The efficient use of such a system for homes, residential, and commercial buildings in Iraq will be estimated. This work is part of ongoing efforts of the Center for Energy and Renewable Energies Technology Center at the University of Technology to raise awareness and education in using renewable alternatives in Iraq [15-65].

II. EXPERIMENTAL SETUP

In this study, a transparent solar collector to heat the air was designed and manufactured. The collector was designed to heat air of the room in the city of Baghdad atmospheric conditions. The primary structure of the collector was constructed by a wood sheet of 1.5 cm thickness. This material was used because of its low price and it is an excellent heat insulator. The designed wall surface area is 1 m^2. A wooden board of 0.5 cm thickness used to divide the air way into two passages. A flat aluminum plate with a thickness of 3 mm and dyed in non-selective black color was fixed on the face of the plank facing the sun and the entire collector was covered by a transparent glass with a thickness of 3 mm. Fig. 3 shows the manufactured air heater collector used in this study. The collector was designed to be tilted at an angle of 45° to receive the highest level of sunlight in Baghdad winter. Several thermocouples type B were used to measure the temperatures in variable parts of the wall, particularly in the inlet and outlet. In this study, the movement of air depends on the free convection resulted from the temperature difference between the inlet and outlet air due to the small collector measures and to increase the heat transmitted to the air during the heating process.

Fig. 3 The transparence solar air heater used in the study

The heat gained by the aluminum plate was calculated as:

$$Q_p = m_p . C_p . \Delta T_p$$

The heat gained by the air

$$Q_{air} = m^o_{air} . C_{p_{air}} . \Delta T_{air}$$

$$m^o_{air} = \rho_{air} . A . V$$

Where:

A- The inlet of the collector area= 0.2m^2

V- Air velocity.

As the air heater depends on solar radiation and must be fixed in an area far from shadow, it is reasonable to estimate that the solar air temperature has an effect on the heated air as well as the air temperature. The solar air temperature was calculated by the equation:

$$T_s = T_o + \alpha \frac{I_t}{h_o} - E \frac{\Delta R}{h_o}$$

Where:

I_t: Total solar intensity (W/m^2)

T_o: outside air temperature (^{o}C)

E: emissivity

ΔR: the radiation exchanging

h_o: external surface heat transfer coefficient

III. RESULTS AND DISCUSSIONS

The most effective factors affecting solar air temperature are the external air temperature and the sun intensity, Fig. 2 represents the differences between the averages of the ambient air temperature and the calculated solar air temperature for the tested period. The solar air temperature was higher than the ambient temperature with about 106.7%. This increment indicates the high solar intensity for Iraq at winter. The average measured solar intensity was ranged from 134 to 346 W/m^2, as Fig. 5 manifests.

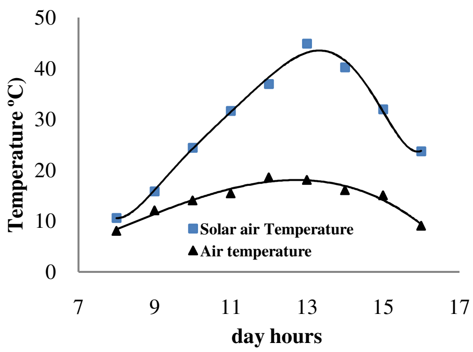

Fig. 4:Air temperature distribution during the day

This high solar intensity gives an impression that solar power in Iraq could be exploited for all heating applications either hot air or water for homes or industrial projects are possible and will achieve success and reduce the consumption of the fossil fuels used for this purpose.

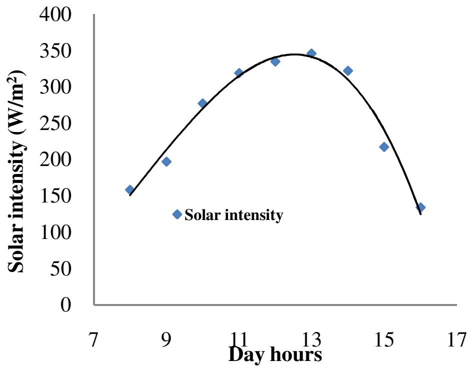

Fig. 5:Solar intensity distribution during day hours

Fig. 6 represents the temperature of the aluminum plate and the heated air during the tests which started at 8 AM and ended at 4 PM. The aluminum plate gained the temperature from direct solar radiation and the reflected radiation from the transparency glass, which heated it to high temperatures. The aluminum plate temperature rose about 142.45% compared to the ambient air temperature. The recirculated air was heated by the natural convection heat transfer from the plate to it. The heat transfer rate depends on the coefficient of heat transfer between the air and the aluminum plate. The temperatures difference between the aluminum plate and the heated air was 16.78% which indicated the high conviction rate resulting in a high efficient heating process. The air was heated about 101.74% higher than the ambient air along the day hours.

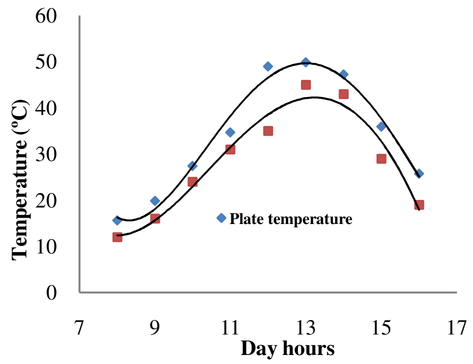

Fig. 6: The plate and heated air temperature during day hours

Fig. 7 represents the thermal energy gained by the plate and the air during the heating process. The aluminum plate gained about 130.08% of the increased thermal energy of the heated air. The reason for this difference is the movement of the heated air, and this movement is increased by increasing its temperature. However, this movement speed was low as it depends on natural convection process, as Fig. 8 declares.

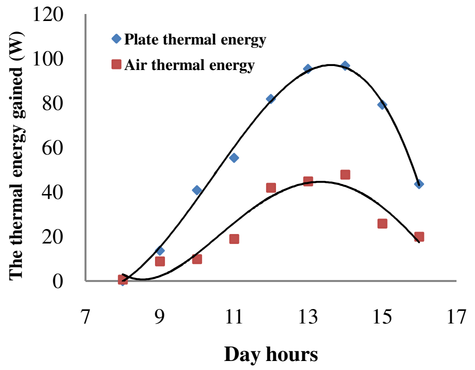

Fig. 7:The thermal energy gained by the plate and heated air during day hours

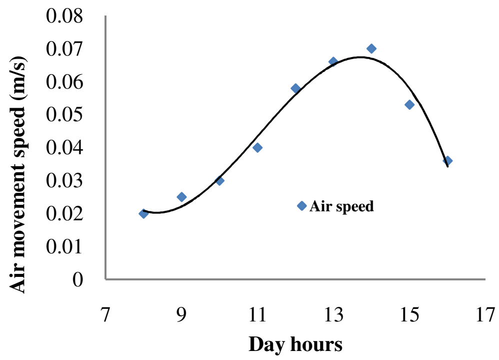

Fig.8: Heated air movement speed during day hours

IV. CONCLUSIONS

In this research, a transparent air heater was designed and manufactured to work in the winter conditions of Baghdad, Iraq. The intensity of solar radiation in Iraq is high enough that makes heating applications successful to a large extent. The results showed that the preheated air could increase the temperature of the used air to 101% higher than the ambient air. The employed aluminum plated was a reasonable choice as the heat transfer convection rate between it, and the air was high. Air movements due to natural convection were linked to the circulated air temperature and commensurate with the intensity of solar radiation.

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[2] U.S. Energy Information Administration. 2008. 2003 Commercial Buildings Energy Consumption Survey. Table E1A. Major Fuel Consumption (Btu) by End Use for All Buildings. These totals are based on “site” or

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