A Thermal Energy Recovery System and its Applications in Building

(A Short Comunication)

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ABSTRACT

In this paper a heat recovery system from oil heater as a water heater is proposed and analyzed. The potential of heat recovery is studied technically and economically. A model was built and experiments on it are discussed. Recovery of waste heat from the oil heater stack and its application in building is proven to be economically beneficial. The most part of this apparatus was a double-walled tanks and oil heater stack act as firebox for water heater. This tank with 200 liters volume was made of galvanized iron sheets and painted with black color for adsorption of solar radiation. The tank of water heater was filled with 12-15$^{\circ C}$ water. Sampling was performed at 8 in the morning to 8 at night during one week. The analysis results show that the heat recovery system is recognized as a well option for the examined residential building from both economic and environmental points of view. With the operation considering optimal economic benefits, cost is reduced by about 50%. With maximizing the environmental advantages, CO_2 emissions are decreased.

Key words: Domestic water heater, Thermal energy recovery, Temperature, Oil heater, Stack

INTRODUCTION

Thermal energy recovery is one of the most advanced energy technologies. Recently, much attention has been paid to use of these systems in buildings [1].Domestic water heating (DWH) is reported to be the second largest energy end-use for households. "Several strategies were suggested for reducing the amount of energy required in residential DWH, including energy efficient water heaters, methods of heat recovery, and systems that use renewable energy like solar water heaters"[2]. Methods of heat recovery should allow minimum thermal energy losses, leading to energy savings [1].

In thermal energy recovery or storage system, energy is saved by changing the temperature of the storage materials (e.g. water, oil, bricks, and sand, soil or rock beds) and a thermal energy storage (¬TES) system consists of a storage medium, a tank and input/output devices [1].The ability of storing wasted heat in a tank depends on the value of the material [3]. At low temperature water is one of the best storage media. It has higher specific heat than other materials, and it is inexpensive and widely accessible. Water can be used over a wide range of temperature, say 25-900$^{\circ C}$. For a 600$^{\circ C}$ temperature change, water will store 250KJ/kg or 2.5×105KJ/m^3. Hot water is required for washing, bathing etc., and it is commonly employed in radiators for space heating. Consequently, it is the most widely used storage medium today for solar based warm water and space heating applications [4] Water storage tanks are made from different materials, like steel, aluminum, reinforced concrete and fiber glass. The tanks are isolated with glass wool, mineral wool or polyurethane. The sizes of the tanks used vary from a few hundred liters to a few thousand cubic meters [4]. According to previous studies, using the thermal energy recovery system and its applications in the building we are able to minimize annual energy cost, annual CO_2 emissions and other pollutant gases [5]. Five countries- Japan, Germany, UK, the Netherlands and USA- are very active in the field of research of thermal energy recovery and its applications in building [6-7]. The Research and Studies Center of Environment and Energy in Iran has shown that oil fuel combustion produces 35% of total greenhouse gases in this country. Urban and rural areas, due to lack of access to natural gas fuels, commonly use the oil fuel in heater and water heater. Based on reports, after vehicles, domestic combustion equipment is the twice environmental pollutants. In domestic heater and heater water there is not any exchanger for recovery of waste heat. It is cleared that hot gases and heat without any recovery process have been emission into the environment [8-9].Therefore, the purpose of this study was investigation the efficiency of waste heat recovery from the oil heater and its application in domestic heater water.

MATERIALS AND METHODS

This study was an experimental and sectional study that performed in Tabas city from Khorasan Shomali province. Here the potential of waste heat recovery was studied practically. Domestic heater in this study was an oil heater burned 10 liters daily. The most part of this apparatus was a double-walled tanks and oil heater stack act as firebox for water heater. This tank with 200 liters volume was made of galvanized iron sheets and painted with black color for adsorption of solar radiation. To reduce heat losses, Interior wall was covered by thermal isolation jacket. Water heater dimensions (height× diameter) were 1540× 530mm. But stack dimensions exited from the water heater were 1000× 150 mm. Both cold and heat pipe diameter was 2.1 inch. ¬Water heater connected to stack was located on the roof, while oil heater was the indoor of the building. The tank of water heater was filled by 12-15$^{\circ C}$ water.

Sampling was performed at 8 in the morning to 8 at night. During a week sampling, the average wind velocity was measured and found to be 0.29±0.21 m/, that is, velocity wind was slow. Water heater flow rate was 8.3 l/h. The estimate of average operational cost was based on oil consumption rate 0.41 l/h, with a density of 860 kg/m^3 and price per liter oil was 1500 Rails [10].

For produced gases calculation, the oil utilized in the heater was assumed to have the following formula ($C_{12}H_{26}$), therefore, the combustion process can be represented by the following equation [10]:

$$C_{12}H_{26} + 18.5O_2 + 69.56N_2 \longrightarrow 12CO_2 + 13H_2O + 69.56N_2 \quad (1)$$

Also based on Eq.2 saved thermal energy by water was calculated [11]:

$$Q = mCp \times \Delta\theta \quad (2)$$

Where:

Q is the saved thermal energy of water in KJ/○C

m is the mass of water in water heater in kg

Cp is the specific heat capacity of the substance in KJ/Kg○C

$\Delta\theta$ is the temperature difference in ○C

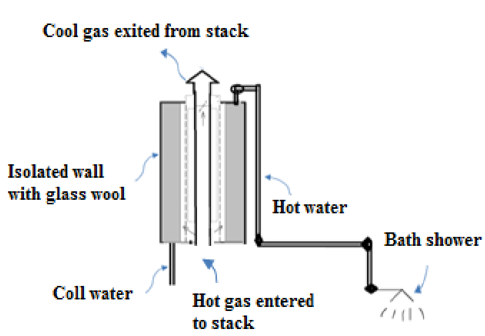

Fig 1. Cross- section of water heater fabricated in this study

RESULTS AND DISCUSSION

According to the obtained results from this study was cleared that the water heater temperature was 47.36±4.36 $^{\circ C}$ (table 1). In this field, study of Sadeghzadeh showed that water temperature existed in heater water was reached to 45$^{\circ C}$ of recovered waste energy [12]. But, Alkhamis et al in a study with the title of utilization of waste heat from the kitchen furnace of an enclosed campus showed that the temperature difference was 25.38±11.46$^{\circ C}$ [10]. Other studies also have explained that temperature of the warmed water by recycling waste thermal energy is suitable for washing baths or other building activities. Because of having high specific heat capacity, it is cleared water is a suitable option for saving waste thermal energy[13].Exhaust temperature of fabricated apparatus was 91.61±3.11$^{\circ C}$ (table 1). Sadeghzadeh in your study has shown that the exhaust temperature from domestic heater after waste heat recycling is 100-185$^{\circ C}$ [13]. In another research with title: study of low-grade waste heat recovery and energy transportation systems in industrial applications has been pointed that waste heat recycled from industries with low grade temperature is able to decrease temperature exited from stack significantly[14]. Saved energy content in this study was 292 ± 11.7 KJ/Kg$^{\circ C}$ (table 1).The results of the research indicate that more than 60% of the waste heat from the kitchen furnace is recovered [10]. Also Tanha et al in study of two domestic solar water heaters with drain water heat recovery units found that these systems are able to recovery 789 KWh heat annually with an overall efficiency of about 50% [2]. But sadeghzadeh has reported 13% thermal efficiency [12]. Also according to other reports in a rotary heat regenerator, the outlet exhaust temperature before heat recovery and after recovery was 100$^{\circ C}$ and 35$^{\circ C}$ respectively. In this study, percentage heat recovery was 55% [14]. Noureldin has shown that waste energy recovery in Bisphenol-a plant can result in more than 17% saving in hot utility consumption [15]. According to Chitcheian study, simultaneous energy production can reduce waste energy. According to Chitcheian reports, total efficiency of simultaneous processes is 80-90%, but this amount is 40-50% in conventional processes [8]. In another study, amount of thermal efficiency from boilers was 93.91% which 7.04% was higher than the existing CB [16]. Also, drain water heat recovery (DWHR) system has showed the capability of an annual heat recovery of 789 kWh and an overall effectiveness of about 50 % [17]. But, other studies in this field, efficiency of waste heat recovery were cited equal to 10% [18].

Table 1. Summary of the results obtained from performance of the fabricated water heater

Variables	Amount of variables			
	Min	**Max**	**Average**	**Standard deviation**
Water heater temperature ○C	40	56	47.36	4.36
Exhaust temperature ○C	85	97	91.61	3.11
Saving energy content KJ/Kg.○C	250	367	292	11.7

Based on many studies, a thermal energy recovery system is an important element of energy saving programs in buildings. This system is mainly installed to lower initial costs and operating [1]. It is suggested that in light of growing environmental concerns heat recovery technology could play an essential role in the reduction of environmental pollution. The utilization of heat recovery systems simply reduces the energy consumption and hence leads to two most significant benefits: (i) conservation of fossil fuels and (ii) reductions in CO_2, SO_2, NOx and CFC emissions [1, 19]. CO_2 reduction is a main consideration for the introduction of heat recovery systems. Equation 2 illustrates CO_2 emissions of oil consumption. The adoption of all heat recovery alternatives has an environmental benefit. The fuel cell system with minimum-emission operation leads to the largest CO_2 reduction, which is about 9% less than the conventional system [5]. It can be found that the operation of both two systems with one fuel source leads to considerable cost reductions. The heat recovery system with minimum-cost operation has the least annual energy cost, which is about 50% less than the conventional energy system(if water heater burned oil equal to the heater). Furthermore, heat recovery system has a relatively higher economic efficiency than the conventional system. According to results of Ren et al, cost reduction with different operating modes for residential building in Japan was 26% [5].

CONCLUSION

In this study, a heat recovery system has been analyzed from both economic and environmental viewpoints. As a case study, a typical residential building located in Tabas, Iran has been examined. According to the obtained results, the following conclusions can be gathered:

1.With the heat recovery system, energy cost is minimized.

2.From the economic point of view, the heat recovery system with minimum-cost operation is the optimal option for the assumed residential building in Iran.

3.From the environmental point of view, the heat recovery system with minimum CO2 and other gases emissions operation gets the best result with an air pollution reduction.

Generally, it can be found that the use of the heat recovery system results in large economic worth due to the motivation policies supplied by the government. Therefore, in the future, some new activities should be performed into account. For example, some renewable energy resources may be used for energy recovery in buildings. Also, to make a better use of the recovered heat, a regional heat network can be formed among multiple households to balance the heat supplies and reduce the energy losses.

ETHICAL ISSUES

Ethical Issues such as plagiarism have not been observed.

CONFLICT OF INTERSTS

Authors announce that is not any competing interest.

ATHORS' CONTRIBUTION

Chavoshani was director of this study and Akbari conducted it.

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