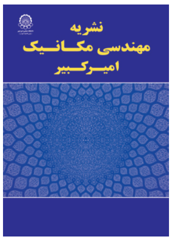

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Experimental Investigation of Using Phase Change Materials in Heating System of a Solar Greenhouse

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ABSTRACT: The use of solar greenhouses has increased manifold over the last two decades and this is the main reason for thermal systems development in greenhouses. Most of the energy sources are not reliable because of the environmental problems and continuous climb in energy prices, thus using renewable and pure energies such as solar energy in the thermal systems is very important. In this paper, the use of phase change materials in the heating system of a model solar greenhouse in Dezful is analyzed and discussed experimentally. A model greenhouse with a ground area of 3 m2 has been coupled with a heating system that consists of two flat collectors and a water store that contained 18 kg paraffin wax (latent heat 190 kJ/kg and melting point 55ºC) as phase change material. Temperature variations of soil, greenhouse, and ambient were evaluated to indicate the thermal performance of this energy storage system. Results of this study indicated that the maximum average temperature of a store during energy storage is 67ºC . Over the night in the heat dissipation cycle, the rate of heat transfer and the temperature difference between inlet and outlet of the store is higher in earlier hours in comparison with later hours due to the high-temperature difference between store and greenhouse. The minimum night time temperature of greenhouse rose by 3ºC and nighttime greenhouse average temperature increased by 4ºC. Furthermore, a 6-8ºC increased in temperatures of soil in different depth was achieved.

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1- Introduction

The use of solar greenhouses has increased manifold over the last two decades. Temperature is one of the most dominant parameters affecting the performance of a greenhouse. An appropriate thermal system can be coupled with the greenhouse to have an optimum temperature. Latent heat storage using phase change materials (PCMs) is one of the most efficient ways of storing thermal energy. In fact, PCMs are used as a storage medium in these systems. A wide range of investigation into the use of PCMs for energy saving in greenhouses has been carried out [1-4]. All studies imply that PCMs could be used for energy storage control in the greenhouse. In most of the investigations only solar air collectors have been used. In the present study, the thermal performance of an energy storage system including solar water collectors is discussed and the heating of greenhouse air is studied as well as heating of the greenhouse bed soil.

2- Thermal Energy Storage

Thermal energy storage can be done by sensible heat, latent heat and thermochemical or combination of these. In a sensible heat storage, the amount of heat stored can be calculated as follows [5]:

$$Q = \int_{T_i}^{T_f} mC_p dT = mC_{ap}(T_f - T_i) \tag{1}$$

This quantity depends on the amount of storage material, the specific heat of the storage medium and the temperature change. In these systems to increase the amount of energy stored, we should use a larger volume of material.

Latent heat storage is based on the heat absorption or a release when a storage material undergoes a phase change. The amount of heat stored in the latent heat storage system is given by [5]:

$$Q = \int_{T_i}^{T_m} mC_p dT + ma_m \Delta h_m + \int_{T_m}^{T_f} mC_p dT \tag{2}$$

$$Q = m[C_{sp}(T_m - T_i) + a_m \Delta h_m + C_{lp}(T_f - T_m)] \tag{3}$$

Latent heat thermal energy storage has advantages such as high energy storage density and constant temperature during energy absorption or release. Because of these characteristics, latent heat storage is particularly more attractive than sensible heat storage.

3- Experimental Procedure

The schematic view of the greenhouse and heating system is seen in Fig. 1 The experiments were performed at the solar research center of Jundi-Shapur University in Dezful. The greenhouse shape is even-span with 2 m length, 1.5 m width and 1.9 m height at the center. The east-west orientation is chosen for the greenhouse because it is best suited at almost all latitudes. This orientation receives a greater radiation in winter in comparison with the others [6]. The heating system consists of a copper heat exchanger with 28 m length and 0.63 thickness, two flat solar water collectors with 1.71 m2 and 1.73 m2 surface area each and a water storage that contains 98 aluminum tubes with 180 ml paraffin wax each with a melting point of 55ºC and latent heat 190 kJ/kg. The storage was insulated by the glass wool to minimize the heat loss during data logging.

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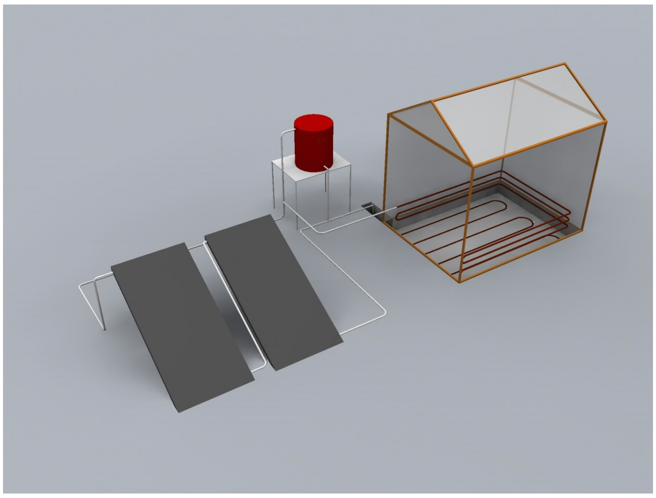

Figure 1. Schematic view of the greenhouse and heating system

4- Results and Discussion

During the day time, the energy of solar radiation was absorbed by collectors and stored in PCMs. This stored energy is released during the night for thermal heating inside the greenhouse. The sensors were inserted into a store, inlet, and outlet of the store, different heights of greenhouse and different depth of soil for measuring the temperatures. The cycle of heating started at 19:45 for the greenhouse. In Figs. 2 and 3, the temperature of greenhouse and ambient are seen (for a typical night). As it is obvious from Fig. 2, temperatures of greenhouse and ambient are the same without heating condition.

Table 1. Temperature of greenhouse and ambient (ºC)

	Min of ambient	Min of greenhouse	Ave of ambient	Ave of greenhouse
without h.	6.2	6.4	9.1	9.3
without h.	5.3	5.8	7.7	8.2
with h.	5.4	9	8.6	12.8
with h.	6.1	9	9	12.3
with h.	6.1	9	9.1	12.1
with h.	4.5	8.8	7.9	12.8

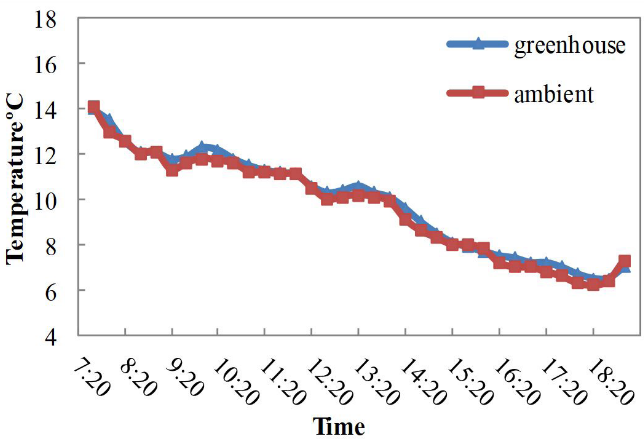

Figure 2. Temperature variations without a heating system

Average temperature and a minimum temperature of greenhouse and ambient are seen in Table 1 for six continuous nights. As can be seen in Table 1, minimum nighttime temperature of the greenhouse and ambient are almost equal without heating conditions.

In Figs. 4 and 5, the temperatures of soil in different depths are seen (in a typical night). In case of without heating condition, the temperatures of all depths dropped down about 10ºC at night.

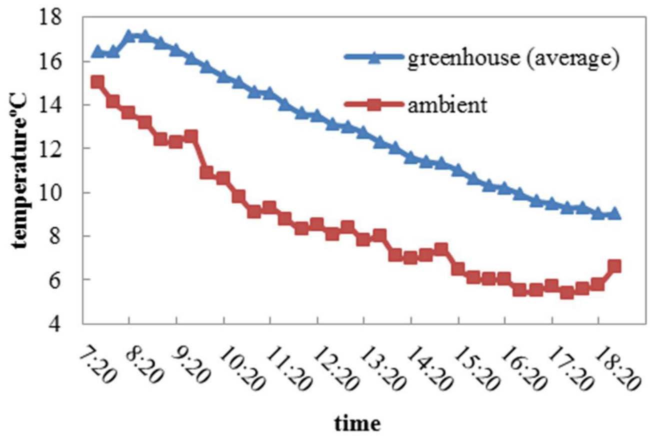

Figure 3. Temperature variations with the heating system

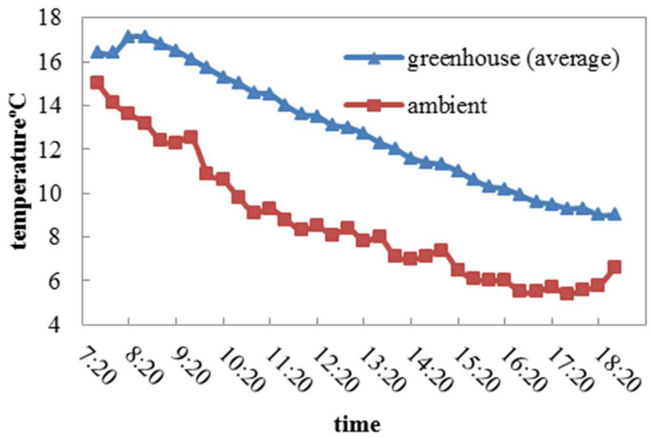

Figure 4. Temperature variations without a heating system

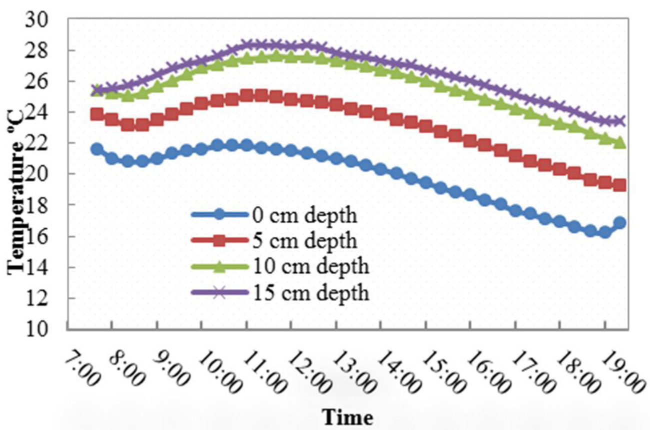

Figure 5. Temperature variations with the heating system

5- Conclusions

The greenhouse minimum night time temperature rises 3ºC with this heating system. The Night time greenhouse average temperature is increased by 4ºC. Furthermore, a 6-8ºC increase in temperatures of bed soil in different depths was achieved. More than 50% of the heating load of the greenhouse was supplied with this heating system.

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