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Research Article

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Research on heating system of electrical assisted-solar energy thermal storage

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ABSTRACT

In this study, an experimental facility the heating system of electrical assisted-solar energy storage with phase change material was built. The experimental system includes heat pipe type solar collector, heat storage device, and vacuum phase-changing radiator, pump and controlling system. Through the experiment, the operating characteristic of the heating system is obtained. The experimental results show that the systems have super-performance of heat storage and heat release, can satisfy the requirement of heating system.

Key words: Solar energy, heating system of thermal storage with phase change material, operating characteristic

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INTRODUCTION

Solar energy is the source of all the energy we need in human life, which has much more advantages than others. At present, solar energy has been widely used in hot water supply, heating, air conditioning, refrigeration and power. And it also appears the comprehensive utilization of solar energy eco-building. But there are some contradictions between the application and the law of solar radiation: When the weather gets cold, people need more calories; the supply of solar energy often shows insufficient. When the solar energy appears shortage, we have no choice but to use other energy or other technical means. Heat storage technology is one of a good solution to shortage of solar energy.

Literature [1] uses naphthalene as a thermal storage material to study its storing and releasing heat process in phase thermal storage device of a new type of aluminum ribbed slab, which is internal naphthalene melting and solidification. The result shows that the device plays admirably the role of heat exchanger components and the inlet temperature and flow rate of hot fluid have important implications on the rate of storing and releasing heat. CHEN Li et al. [2] introduces a heating system of solar energy storage with phase, which can avoid the insulation effects and can take advantage of the low ebb electricity. Jiang Yiqiang et al. [3], [4] propose a suitable structural form of the phase thermal storage units with the type of cylindrical shell tube. Then, based on the method of enthalpy we establish a mathematical model of thermal storage unit and prove its correctness according the result of literature.

Mehmet Esen, UrosStritihand Kang Yanbing[5-7] study the performance of the casing thermal storage device.

In this paper, experimental table of the heating system of electrical assisted-solar energy storage is built with heat pipe type solar collector, pump, phase-change thermal storage device, auxiliary electric heater, Data Acquisition instrument, radiating equipment and so on. The operating performance of heating system of electrical assisted -solar energy thermal storage with phase change material is studied by actual operation in winter.

EXPERIMENTAL SECTION

EXPERIMENTAL DEVICE

The schematic diagram of this experiment device is shown in Fig.1.

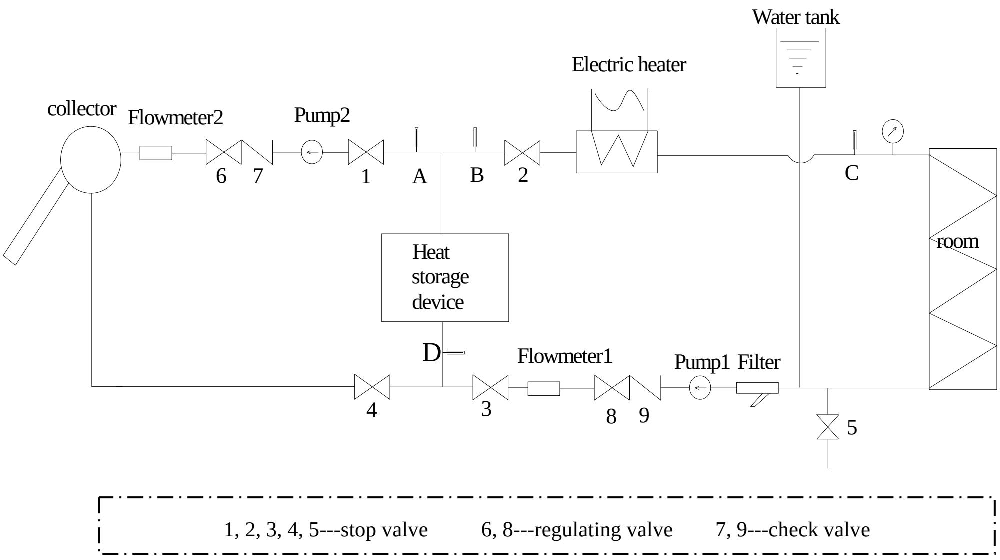

Fig. 1: Schematic diagram of heating system

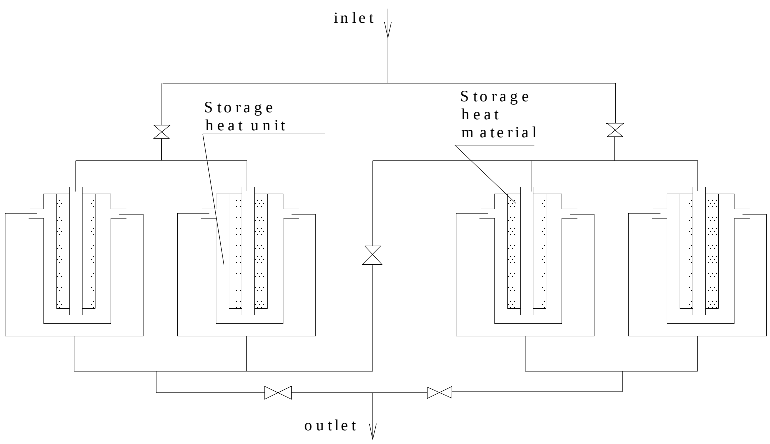

Fig.2: The schematic diagram of storage heat unit

THERMAL STORAGE DEVICE

The experimental facilities applies the phase change thermal storage unit with bushings between double flow that proposed by the group. The main part is three tubes, the inner and outer layers are the channels of heat transfer fluid and the phase change material is between the two layers. The height of the inner tube is 1100mm, the outer diameter is 32mm and the wall thickness is 2mm. The heat transfer fluid, after heating, directly flows into the inner tube, which is connected to the heating side directly, to exchange heat with the phase change materials which is outside of the inner tube; the outside of the inner tube has a casing, its outer diameter is 159mm, the wall thickness is 3mm, the height of the casing is 950mm, the bottom of the casing is sealed with the stainless steel plate of 2mm. A hole is open with diameter of 32mm on the stainless steel plate for insertion of the inner tube. The length of the inner tube stretching out is 20mm. between the inner tube and the casing is full of the phase change material. Put the connected two layer casing into the outer tube. The height of the outer tube is 1000mm, the outer diameter is 200mm and the wall thickness is 2mm. The bottom of the outer tube is sealed with the stainless steel plate. We set a 140mm stent in it, which stands in the center of the heat tube and has the function of fixing the inner tube and the phase change materials casing. The heat transfer fluid, through the inner tube baffle, flows into the outer casing at the bottom of the outer tube to exchange heat with phase change materials. This structure is equivalent to extend the heat transfer fluid channel, increase the heat exchange area greatly. So the heat exchange efficiency is improved significantly.

In order to meet the heating requirements, we use four thermal storage units to do the experimental research on the heating system of electrical assisted-solar energy storage with phase change material. Four heat storage units are divided into 2 groups in the system and each group has two storage units which are operating in parallel. The valves are set up between the two groups. We can achieve the purpose of switching between the two groups through the valves switching. The thermal storage unit connection diagram is shown in Fig.2.

SOLAR COLLECTOR WITH HEAT PIPE

The parameter of heat vacuum tube solar collector shows in Tab.1.

Tab.1: Relative parameters of heat pipe collector

Type	C4-SD1×16
Number of tube	16 支
Overall dimension(mm)	2126x2065 x175
Heat absorption area(m^2)	2.9
Weight(kg)	100
water storage capacity(L)	1.5
operating temperature(℃)	70-120
Maximum operating temperature(℃)	190
Maximum stagnation temperature(℃)	250
Minimum working temperature(℃)	-45
rated working pressure(bar)	6

HEAT STORAGE MATERIAL

In this study, the phase change thermal storage device is used for heating system with low temperature water. After filtering we determine apply the JDJN-58 phase-change material. The physical parameters of the type are shown in Tab. 2.

Tab.2: Thermo-physical properties of material

Thermo physical properties	values

Melting point(℃)		56-58
Latent heat(kJ/kg)		230
Specific heat(kJ/kg℃)	Solid	1.50
	Liquid	2.1
Thermal conductivity(W/m℃)	Solid	1.12
	Liquid	0.58
Density(kg/m^3)	25℃	1460
	35℃	1420

ELECTRIC HEATER

Electric heater is an auxiliary heat source in the circulatory system, which is opened automatically when the outlet water temperature in the heat storage cylinder in the exothermic process cannot reach the heating supply (40℃). In this system three electric heating rods are put inside the electric heater. One of them input power is 1500w, the input power of others are 1000w.

MEASURING POINT ARRANGEMENT

The outlet and inlet temperature of solar heat collector and thermal storage device, the inlet and outlet temperature of the heating side and the outdoor temperature are measured during the process of studying. The copper-constantan thermocouple is used for measuring the temperature. The system has 19 thermocouples to measure the temperature trends of heat storage materials, thermal storage device, solar heat collector, the radiator's inlet and outlet. The temperature signs is accessed to the FLUKE 2645A and automatic the temperature is recorded automatically. The flow is measured by float flowmeter. The accuracy of the float flowmeter is 1.0.

RESULTS AND DISCUSSION

The typical outdoor climate parameters are chose in December and the average outdoor temperature is -12℃. The temperatures of the thermal accumulator inlet and outlet variation with time are showed in Fig.3. It can be seen that the heat is collected by the thermal accumulator can cause the temperature of the phase change material reaching the phase transition temperature (56-58℃). The temperature of the thermal accumulator can reach the phase transition temperature in three hours since the system operated. When the water-supply temperature reaches the phase transition temperature (56-58℃), the system begins to store heat. The temperature difference of water-supply and backwater maintains at about 7℃. The maximum water-supply temperature is 72.5℃ and the lowest is 57.8℃; the maximum temperature difference of water-supply and backwater, which is 7.62℃. It can meet the requirements of the thermal storage. When the water-supply temperature reaches the phase transition temperature (56-58℃), the thermal accumulator begins to store heat, at the same time the temperature of water-supply and backwater maintains at 61±1.5℃. With the reduction of the solar radiation, the temperature of water-supply and backwater begin to decline

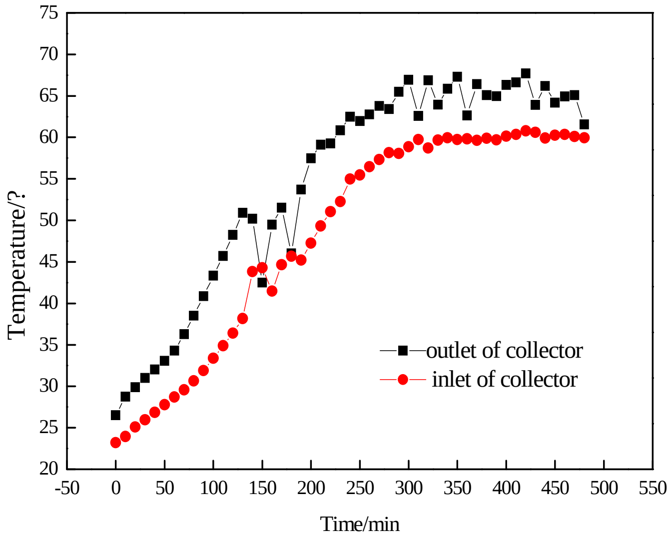

Fig.3: The temperature variation of inlet and outlet with time

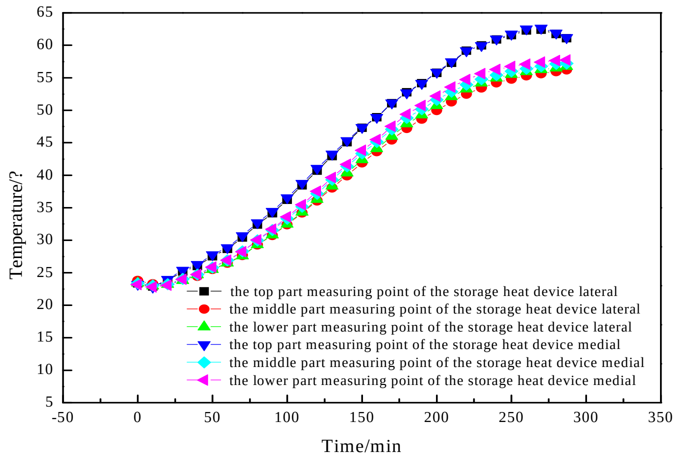

Fig.4: The temperature variation of phase change material with time

Fig.4shows that the temperature variation of the heat storage material with time in the thermal storage process. It can be seen from the figure, when the temperature reaches the phase transformation temperature, the temperature of the heat storage material in the thermal accumulator, the maximum temperature achieves 61.5℃ and the lowest is 57.2 ℃, maintains at 58±3℃. The distribution of temperature in the thermal storage device is uniform extremely. the temperature of the material close to the upper inside the thermal storage device is the highest, the reason of which dues to the thermal storage device applied the form of upper inlet and bottom outlet, and the hot fluid passing through the inner casing. Throughout the phase change process, the stage of the sensible heat and the latent heat is obvious during the process of the phase change. But the overheating stage is not. The reason is the lower water-supply temperature, the slow heat storage process and the insufficient of the solar energy providing.

Fig.5 shows the temperature variation of the heat storage material with time in the exothermic process. In the figure, it can be seen the three stage of the sensible heat, latent heat and sensible heat, but not obvious. The reason dues to the insufficient of the heat dissipating capacity of the radiating equipment, which leads to the heat doesn't timely shed. Due to using phase radiator in the system, the temperature of phase transition is 32℃; the minimum exothermic temperature of the thermal storage device is 33℃±2℃. In the exothermic process, the middle part of the thermal device releases heat slowest, followed by the bottom part and the upper part are fastest. The reason is that the large temperature difference between the upper fluids and the phase change material.

The flow rate of inlet and outlet is large; the middle part is small, which leads to the inconsistent of the heat level, the flow rate larger, and the heat exchange stronger.

Fig.6 shows the temperature variation of the inlet and outlet with time in the exothermic process in the thermal storage device. It can be seen that the device can stably get heat during the exothermic process. The highest temperature of outlet is 57.38℃, the maximum heat extraction temperature difference is 5.2℃ and the average heat extraction temperature difference is 2.42℃ in 3-4 hours; The heat extraction temperature difference becomes

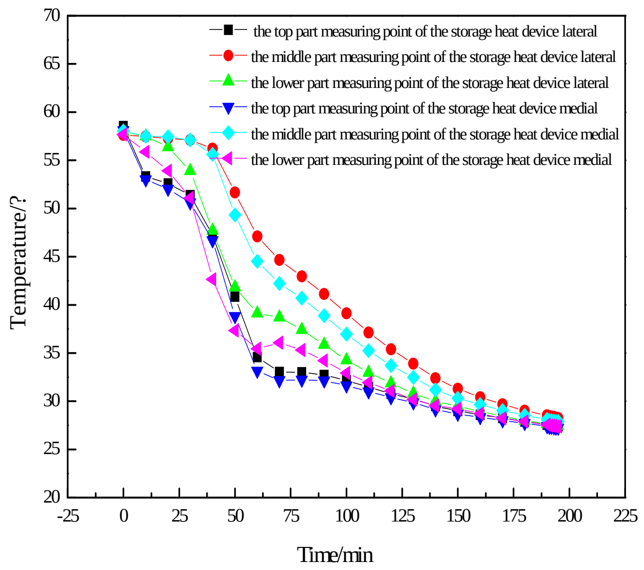

Fig.5: The temperature variation of phase change material with time

smaller with the time, the reason of this phenomenon is mainly because of the large temperature difference in the heat transfer and the adequate thermal supply in the thermal storage device.

CONCLUSION

In this study, the experimental facilities of the heating system of electrical assisted-solar energy storage are built. The system uses the double laminar flow phase-change thermal storage units with the casing type of concentric partition as the thermal device. The experimental system has two groups in series and each one has two thermal storage unites. The equipment includes solar collector with heat pipe, thermal storage device, and the phase-change thermal storage radiator, pipe and control system.

(1) In the experiment, a new type of phase change materials, JDJN-58, is applied, the physical properties of which is

stable. It is easy to store andis solid state at room temperature. After long time running, it can be seen that the phase change material doesn't corrode the heating surface and the thermal storage device.

(2) The process of exothermic and storage of the phase change material can be clearly divided into three stages: stage of sensible heat, latent heat and superheated. From the experimental data, it can be seen that the stage of sensible and superheated have relatively short time and the process of exothermic and storage mainly occurs in the stage of latent heat, indicating that heat is stored mainly through the process of latent heat.

(3) When the temperature achieves the transformation temperature, the temperature of the heat storage material in the thermal accumulator, the maximum temperature is 61.5℃ and the lowest is 57.2℃, maintains at 58±3℃; The temperature distribution in the thermal storage device is almost uniform. The heat that the thermal accumulator collected can reach the phase change heat storage material phase transition temperature (56-58℃). The temperature difference between inlet and outlet of the thermal accumulator can reach the phase transition temperature in three hours since the system operated.

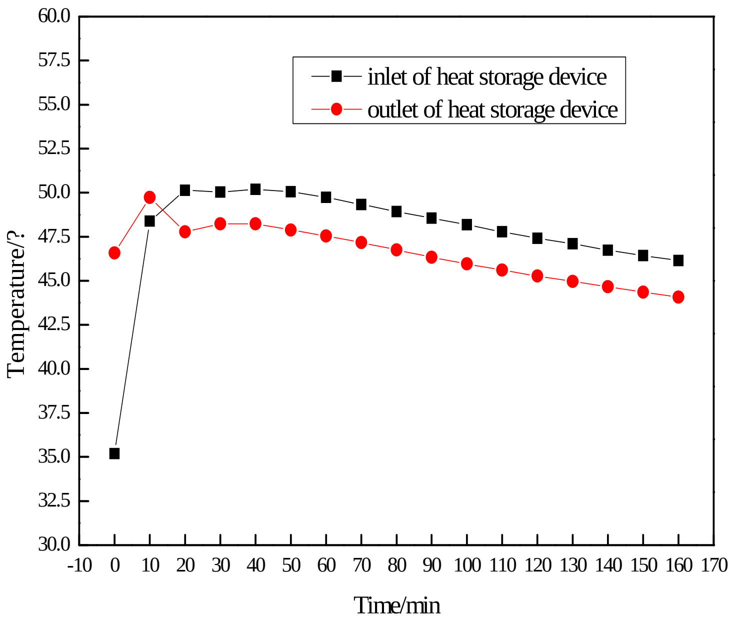

Fig.6: The temperature variation of inlet and outlet of heat storage device with time

When the water-supply temperature reaches the phase transition temperature (56-58℃), the system begins to store heat; the temperature difference of water-supply and backwater maintains at about 7℃; the maximum water-supply temperature is 72.5℃ and the lowest is 57.8℃; the maximum temperature difference of water-supply and backwater, which is 7.62℃, can meet the requirements of the thermal accumulator.

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