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Solar-thermal Underfloor Heating System with Electrical Heating Auxiliary

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Abstract: In this paper, we mainly introduce a solar-thermal underfloor heating system with electrical heating, which consists of solar vacuum tube panel, finned tube heat exchanger, disturbed flow tank, underfloor heating pipe, temperature measuring point, circulating water pump and auxiliary electric heater. Compared with traditional equipment, this system separates underfloor circulating water and domestic water completely. What's more, antifreeze is used to transfer solar energy to underfloor cycling water through a kind of more efficient heat exchanger--finned tube heat exchanger. So residents can not only get warm in winter, but also save more electrical energy.

1. Background

In 2009 at the Copenhagen climate change conference, the 'Low Carbon Economy' was put on the agenda, which is a new economic model based on low energy consumption, low population and low emission. With the global climate becoming more and more warmer, it is commonly believed that the environmental resource destruction and fossil fuel utilization have been important factors restricting sustainable development. What's more, economic and social development is also faced with a lot of serious challenges, such as environmental and resource problems. World Wild Fund (WWF), Climate Group and other international organizations are now making more plans to promote 'low carbon city' construction and development. Therefore, developing a low carbon city has been a new sense of development all around the world.

2. Introduction

Compared with traditional solar energy equipment, this system which concludes antifreeze circulation and underfloor water circulation, separates underfloor circulating water and domestic water completely. To increase the contact area of cycling water and antifreeze, finned tube heat exchanger replaces traditional spiral tube heat exchanger, and the heat transfer efficiency is also higher. Hot cycling water then flows to the underfloor. There are temperature measuring points at the entrance of every room. When the temperature of water is below standard, electrical heating will be operated. In Beijing, for example, every resident can save 106.85 kg standard coal during the whole heating period.

3. Operation Principle

Residents get heat from underfloor cycling water. When ethylene glycol antifreeze is heated to a certain temperature, it will be sent into the finned tube heat exchanger to heat cycling water. After the 50~60℃ water is regulated to a fitted temperature by water mixers, it flows to every underfloor pipes of room with the help of pump. There are valves and temperature measuring points at the entrance of room, which can maintain temperature. When solar energy is insufficient or during the night, electrical heater will be operated. This system can maintain the room temperature between 10~ 20℃.

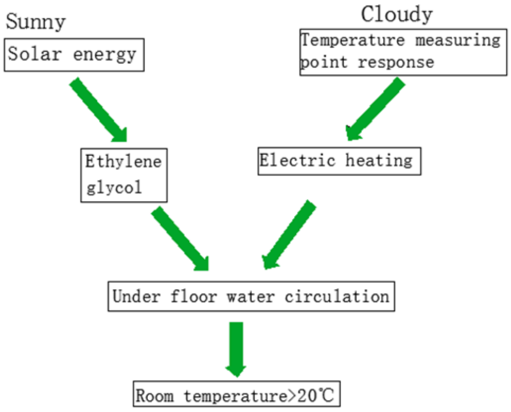

Fig. 1 Working Process of System

4. Designing Scheme

This system is divided into antifreeze circulation and underfloor water circulation. We regard ethylene glycol antifreeze as heating medium, with a low melting point and is difficult to freeze. It is also not easy to frost crack pipes even below 0℃ outside. The hot antifreeze is then sent to the water tank to heat cycling water. In order to let water flow through water tank in the form of turbulent flow, baffles are installed, which can slow down cold water and improve the efficiency of heat transferring. The radius of the U-shaped finned tube heat exchanger is more than 10 mm, so the transfer area is larger. At the same time, the material of the exchanger is brass, which has a higher heat transfer coefficient. When water flow through the mixer, temperature measuring device can adjust the proportion of hot and cold water by virtue of standard temperature. At every entrance of rooms there are temperature alarms, which can start the electrical heater when temperature is low enough.

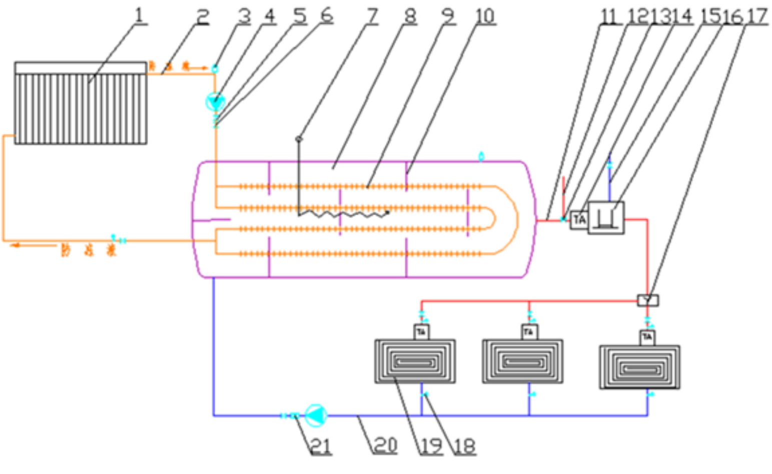

Fig. 2 The structure of system. 1:Solar vacuum tube panels; 2:Antifreeze pipe; 3: Vent valve; 4:Pump; 5: Check valve; 6: Butterfly damper; 7:Electrical heater; 8:Water tank; 9: Finned tube heat exchanger; 10:Baffle; 11:Water pipe; 12: Domestic water pipe; 13: Three-way valve; 14:Temperature measuring point; 15:Cold water pipe; 16:Water mixer; 17: Water knockout drum; 18: Pressure gauge; 19:Underfloor water pipe; 20:Cold water pipe; 21: Pressure valve.

5. Feasibility Analysis

5.1 Conditions

- We use the balcony type vacuum tube panel with the area of 1000×2400×100mm.[1]
- Housing heating area is 100 m^2.
- In Beijing, for example, the heating period is 125 days, from Nov. 15th to Mar. 15th.

5.2 Formula and Instructions

$$\begin{cases} Q = \sum Q_0 \times \eta \\ \eta = \eta o - F_R U_L T^* \end{cases}$$

Q_0	Heat collected by panel
η	Efficiency of solar vacuum panel
η_0	Efficiency of solar vacuum panel when $T^*=0$
$F_R U_L$	Heat loss coefficient of collector
T^*	Normalized difference of temperature
t_i	Inlet temperature of collector working medium
t_a	Air temperature from environment

5.3 Data Collection

Table 1 Temperature in Beijing

Month	**Beijing (Primary temperature of collector working medium)**	
	Environmental temperature t_a /℃	Inlet temperature of collector working medium t_i /℃
1	-4.3	5.1
2	-1.9	4.0
3	5.1	5.1
4	13.6	7.9
11	4.3	11.9
12	-2.2	7.9

Table 2 Monthly Average Solar Energy in Beijing ($\mathrm{MJ}/(m^2 \cdot d)$)[2]

Month	**1**	**2**	**3**	**4**	**5**	**6**
H	15.309	18.443	18.483	18.205	18.416	17.222
Month	**7**	**8**	**9**	**10**	**11**	**12**
H	15.198	15.465	17.481	17.006	15.114	14.205

5.4 Calculation

Table 3 The Whole Energy Collected by Single Resident per Heating Period (MJ)

MONTH	11	12	1	2	3
HEATING DAYS	15	31	31	29	15
ENERGY PER DAY	15.114	14.205	15.309	18.443	18.483
T_i/DGREE	11.9	7.9	5.1	4	5.1
T_a/DGREE	4.3	−2.2	−4.3	−1.9	5.1
PRIMARY ENERGY	226.710	440.355	474.579	534.847	277.245
$T_i - T_a$	7.6	10.1	9.4	5.9	0
$UL \times T^*$	0.7014	0.7543	0.7700	0.8138	0.8690
ULTIMATE ENERGY	159.011	332.169	365.409	435.282	240.926

5.5 Result

We assume that the heat loss coefficient between antifreeze and water circulation is 0.2[3]. Therefore, the area of vacuum tube panel is 2.4m^2. The heat that a single resident can get during a heating period is:

（159.011+332.1685+365.4092+534.282+240.9259）×0.8×2.4=3132.2MJ

Given that temperature can be lower at night in kitchen, living room or others except room. So the heat consumption is less than 20.6 (W/m^2) [3]. Assuming that people sleep for 9 hours at night and the room area accounts for 30% of the house. The correction is as follows:

$$20.6-20.6\times9/24\times0.7=15.2\ (W/m^2)$$

That is, the heat of 1520MJ is equal to electricity of 4200 kW·h.

Thus, the percentage of solar energy is 3132.2/15120=20.7%. In other words, a single resident can get solar energy during the whole heating period is 869.4 kW·h, which is equal to 106.85kg standard coal.

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