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Solar water heating systems applied in high-rise residential buildings in China

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Abstract

This paper introduces the Beijing Meilifang Project and the Tianjin Dingxiuxinyuan Project which apply solar water heating systems with centralized collection & decentralized supply, including their basic composition, operation principle, structure characteristics and operation performance, so as to provide a practicable solution for solar water heating systems installed in high-rise residential buildings. These Projects show that this type of solar water heating system possesses some outstanding features: Economic use and operation, convenient management, balanced benefits, safety and reliability, as well as building integration.

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Keywords: Solar; water heating system; centralized collection; decentralized supply;

1. Introduction

According to the mode of solar heat collection & hot water supply, the solar water heating system applied in residential buildings could be classified into following three categories: centralized collection & centralized supply, centralized collection & decentralized supply, decentralized collection & decentralized supply [1].

So called 'solar water heating system with centralized collection & decentralized supply' is a system which adopts centralized solar collectors and decentralized storage tanks for each family in the building.

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There are lots of high-rise residential buildings in large/medium-sized cities in China. For this feature, centralized collection & decentralized supply system is one of the most suitable systems for solar water heating.

This paper introduces both the Beijing Meilifang Project and the Tianjin Dingxiuxinyuan Project which apply the solar water heating system with centralized collection & decentralized supply, so as to provide a practicable solution for solar water heating systems installed in high-rise residential buildings.

2. The Beijing Meilifang Project

2.1. Project overview

The Meilifang Community is located in Beiyuan Road at Chaoyang District in Beijing, China. There are five residential buildings with a total construction area 160,000 m^2 in the Community; the lowest building has 13 floors and the highest building has 20 floors with all the flat roofs. There are totally 2,112 families living in these buildings, respectively with two rooms or three rooms for each family.

The Project applies the solar water heating system with centralized collection & decentralized supply, which has been put into use since June 2011, as shown in Fig. 1. The solar system adopts heat-pipe evacuated tube collectors with a total aperture area 2,320 m^2. Each family is distributed with average 1.10 m^2 of the collector area.

Fig. 1. Overall view of the Beijing Meilifang Project

2.2. System composition

The whole solar water heating system in the Beijing Meilifang Community includes five independent subsystems, and each subsystem applies the solar water heating system with centralized collection & decentralized supply, as shown in Fig. 2.

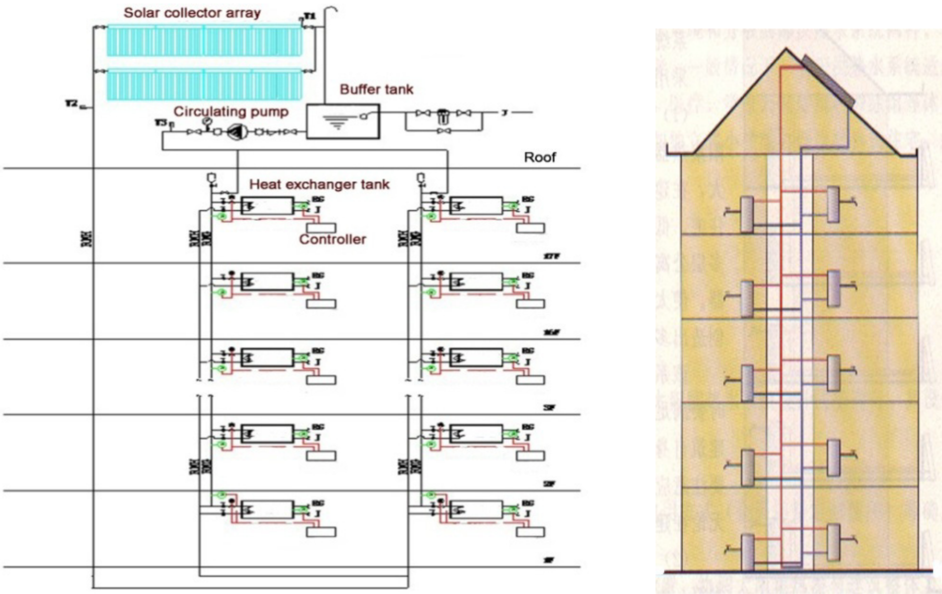


Fig. 2. Schematic diagram of solar water heating system for the Beijing Meilifang Project

Each centralized collection & decentralized supply system is composed of solar collector array, buffer tank, circulating pump, circulating pipelines, heat exchange tanks, water supply pipelines controllers, etc.

The solar collector array along with the buffer tank and circulating pump are installed on the flat roof. Heat exchange tanks are individually placed in bath rooms for each family, and are connected to the buffer tank through the water supply pipelines. Heat-transfer fluid heated by the solar collector array releases the heat to domestic hot water for users through the built-in heat exchanger.

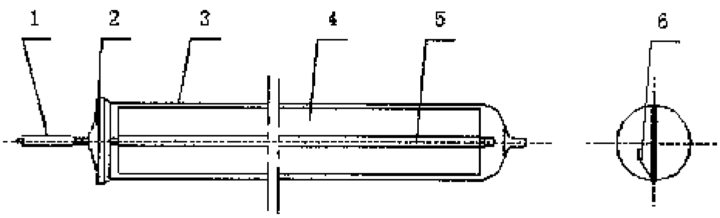
Water is used as heat-transfer fluid for the solar collecting system, and is circulated adopting the principle of differential temperature. In winter season, water inside the pipeline will drain back into the buffer tank as soon as the circulating pump stops at night so as to realize the freeze protection.

2.3. Structure characteristics

In addition to common advantages of ordinary centralized collection & decentralized supply systems, the solar water heating system in the Beijing Meilifang Community possesses two obvious characteristics:

(1) Heat pipe evacuated tube collectors

The heat pipe evacuated tube collector was developed by Beijing Solar Energy Research Institute, and nowadays is produced by Beijing Sunda Solar Energy Technology Co., Ltd., as shown in Fig. 3.



1. Heat-pipe condenser section 2. Metal sealing cover 3. Envelope glass tube
4. Absorber plate 5. Heat-pipe evaporator section 6. Getter

Fig. 3. Configuration of the heat-pipe evacuated tube

As heat-pipe technology is applied to the evacuated tube, therefore the heat-pipe evacuated tube collector has many advantages [2], such as:

- Resistance to freeze due to some effective measures adopted for the heat pipe;
- Fast start-up due to small heat capacity of working fluid inside the heat pipe;
- Low heat losses due to special ‘thermal diode effect’ of the heat pipe;
- Resistance to hail due to high strength of the borosilicate glass tube used;
- High pressure bearing due to metal absorber plate and no touching between heat transfer fluid and glass tube;
- Thermal shock endurance due to the same reason as that above mentioned;
- Reliable and durable operation due to ‘dry connection’ between evacuated tubes and manifold;
- Easy installation and maintenance due to the same reason as that above mentioned.

(2) Heat exchange tanks involving an enamel interior barrel with fins

A tank-in-tank is specially designed for the heat exchange tank, as shown in Fig. 4, which has many characteristics, such as:

- Enamel interior barrel in order to enhance the pressure bearing capability and corrosion resistance of the tank;
- Integrated polyurethane foam in order to improve the thermal insulation property of the tank;
- Interior barrel with fins in order to increase the heat transfer performance of the heat exchanger;
- Magnesium anode protection in order to improve quality of the domestic hot water;
- Built-in electric heater for back-up heating in order to ensure all-weather hot water supply;
- Two volumes of 60L and 80L in order to meet different requirements from two-room and three-room users.

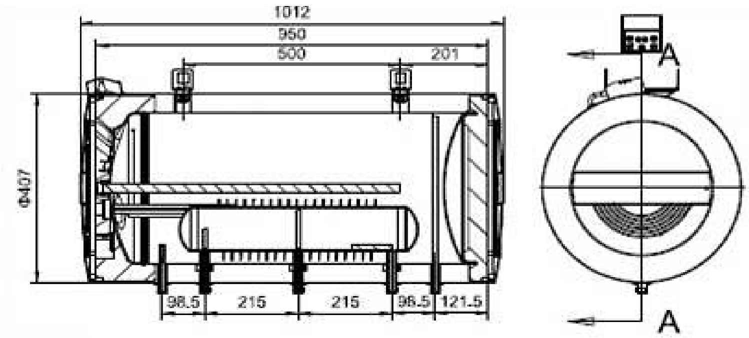


Fig. 4. Configuration of the heat exchange tank involving an enamel interior barrel with fins

2.4. Operation performance

One of the subsystems was tested for the Meilifang Project from 16 February to 20 February 2012, which includes both heat collection performance and heat supply performance of the solar water heating system.

For the heat collection performance, daily average efficiency of the centralized solar collecting system was tested from 9:00am to 5:00pm every day, which was to respectively measure the system heat gain and the solar irradiation over a day; meanwhile the maximum and the minimum ambient temperature were also measured. Test results are shown in Table 1.

Table 1. Test results for daily average efficiency (February 2012)

Test results	16 Feb	17 Feb	18 Feb	19 Feb	20 Feb
Daily average efficiency (%)	43.4	42.0	35.0	44.0	41.6
Max ambient temperature (°C)	16.4	8.7	10.3	14.4	15.3
Min ambient temperature (°C)	–2.9	–2.1	–2.6	–0.7	0.9

For the heat supply performance, hourly average heat gain of each family tank was tested at 5:00pm when users turned on the hot water. Taking 17 February as an example, hourly average heat gain for five family tanks were measured; meanwhile the maximum water temperature was also measured. Test results are shown in Table 2.

Table 2. Test results for hourly average heat gain of each family tank (17 February 2012)

Test results	Room 201	Room 212	Room 901	Room 1601	Room 1612
Hourly average heat gain (kJ/h)	2080.66	1968.76	2240.65	2144.35	2056.15
Max water temperature (°C)	53	54	53	56	54

From test results in Table 1 and Table 2, it can be seen that this solar water heating system with centralized collection & decentralized supply possesses following performances:

(1) Good heat collection performance: Even if in winter season with rather low ambient temperature, the daily average efficiency of the centralized solar collecting system still run in a range of 35% - 44%, so as to meet the design requirements;

(2) Excellent heat exchange performance: Even if in winter season with rather low ambient temperature, the maximum water temperature in different tanks respectively at low-floor, middle-floor and high-floor still reach a range of 53□ - 56□, so as to meet the practical requirements;

(3) Balanced heat supply performance: Within the same solar water heating system, the unbalance among the hourly average heat gain in different tanks respectively at low-floor, middle-floor and high-floor only maintain a range of ± 4.2% - ± 7.7%, so as to meet the users requirements.

3. The Tianjin Dingxiuxinyuan Project

3.1. Project overview

The Dingxiuxinyuan Community is located at Dongli District in Tianjin, China. There are totally 26 residential buildings respectively with 11 floors, 16 floors, 18 floors and 20 floors. Totally 2,424 families live in these buildings. The Project applies the solar water heating system with centralized collection & decentralized supply, which has been put into use since 2009. The solar system adopts heat-pipe evacuated tube collectors with a total aperture area 2,984 m^2, i.e., average 1.23 m^2 for each family, as shown in Fig. 5(a) and 5(b).

(a) Renderings (b) Practical photo

Fig. 5. Overall view of the Tianjin Dingxiuxinyuan Project

3.2. System composition

The whole solar water heating system in the Community includes 32 independent subsystems, and each subsystem adopts the centralized collection & decentralized supply system.

Each subsystem includes a heat-collection circulation and a heat-supply circulation. The heat-collection circulation is composed of solar collector array, buffer tank, circulating pump, circulating pipeline, controller, etc., which are stalled on the sloping roof; and the heat-supply circulation is composed of heat exchange tanks, water supply pipelines, controllers, etc., which are individually placed in the bath rooms for each family and are connected to the buffer tank through the water supply pipelines, as shown in Fig. 6.

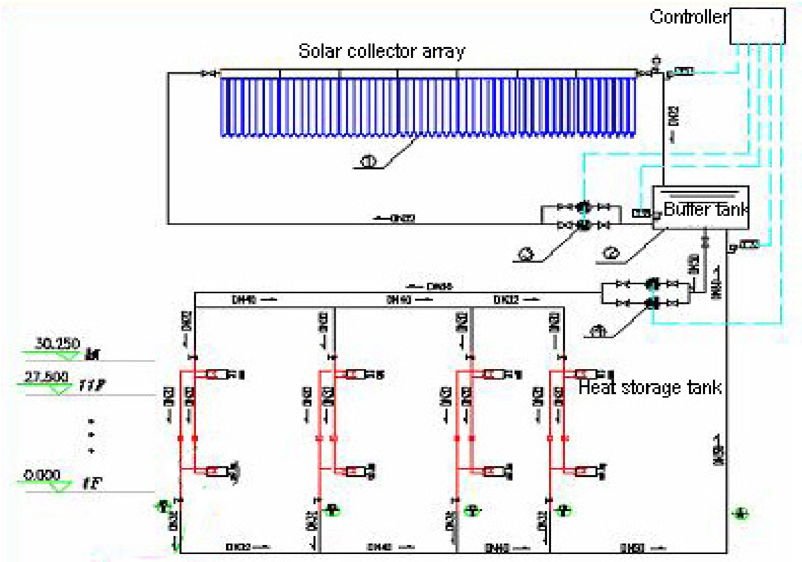


Fig. 6. Schematic diagram of solar water heating system for the Tianjin Dingxiuxinyuan Project

3.3. Operation performance

In order to investigate the heat supply uniformity of the solar water heating system, a middle-floor (6th floor) and a top-floor (11th floor) in one of the buildings have been tested. Test results are shown in Fig. 7.

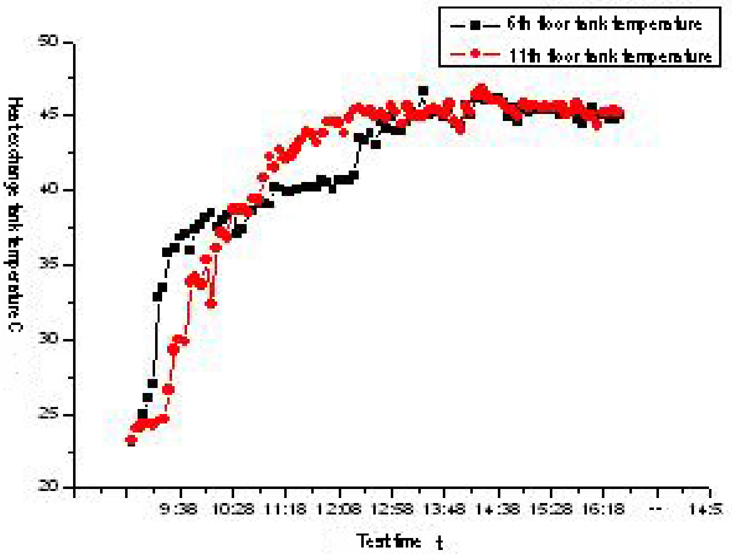


Fig. 7. Temperature variation in two tanks on 6th floor and 11th floor in the same building (2009.10.14）

From Figure 7, it can be seen that initial temperature in two heat exchange tanks were at about 22℃; gradually increased from 9:00 to 13:00 and showed a little different cases; then finally trended to the same final temperature about 45℃ at 15:30. It indicates that the solar water heating system with centralized collection & decentralized supply possesses quite good heat supply uniformity, which is very suitable for the application in high-rise residential buildings.

4. Conclusion

As mentioned above, these two solar water heating systems with centralized collection & decentralized supply of the Beijing Meilifang Project and the Tianjin Dingxiuxinyuan Project have following features:

- Economic use and operation: Users do not have to pay any extra fees, except sharing a little power fee for the public circulating pump and suffering the auxiliary electric heating power fee for their own tanks;
- Convenient management: As all the solar collectors, circulating pump and other equipment are installed at a public space, so it is very convenient to manage and maintain for the property department;
- Balanced benefits: All the residents in the building, including those even if living in the lowest floors, can fairly benefit from the solar collectors installed on the roof;
- Safety and reliability: As solar collectors are collectively installed on the roof, so there are no safety risks compared with that individually installed on the balconies;
- Building integration: Solar collectors can be reasonably installed at the place with good solar irradiation, which has no direct relationship with each family, so as to realize integration of solar systems with the building.

References

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