

# Operation analysis of primary and secondary networks of distributed solar heating system in Tibet

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**Abstract:** Tibet is located in a high cold and high altitude area. Heating in winter is an important problem to be solved urgently, and the distributed solar heating system provides a solution for the efficient and clean utilization of energy in this area. Through the test and commissioning of the distributed solar heating system with supplementary combustion in Tibet, the operation characteristics of the heating system are analyzed from the temperature changes of the primary network and the secondary network. The research results can provide technical support for the application and promotion of the solar distributed heating system with supplementary combustion in Tibet.

**Keywords:** Solar energy; Heating; Supplementary combustion; Distributed energy

## 1 Introduction

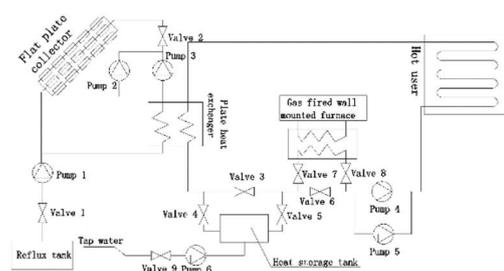
Limited by the lack of fossil fuel resources and the fragile ecological environment, it is impossible to establish a large-scale coal-fired power station with cogeneration for heating, which restricts the heating mode of residents in Tibet [1-3]. Tibet is extremely rich in solar energy, with an average annual radiation of 6000 ~ 8000 MJ / m<sup>2</sup>, an average annual sunshine of about 3000 h and high stability [4,5]. As an important part of the future energy structure, solar energy is mainly used in photovoltaic power generation and solar heat utilization. Solar heating is a green heating method that uses solar radiant energy as a heat source, which not only saves resources but also meets the requirements of environmental protection [6,7]. However, solar energy has the characteristics of instability and intermittence, and can not meet the heating needs of users in special weather [8,9]. Therefore, it is the best choice to adopt multi energy complementary heating mode to form the heating source of Tibet Autonomous Region from the technical and economic aspects [10]. The solar heating system in Tibet is selected in this research. Distributed solar heating can effectively improve the solar assurance rate, and auxiliary heat sources such as gas wall mounted furnace can overcome the disadvantage of discontinuous solar energy and realize the continuous and stable heating of Tibetan residents in winter [11,12]. In this paper, combined with the supplementary combustion solar distributed heating system in Tibet, the heating commissioning test is carried out, and the operation of the system is analyzed from the daily temperature changes of primary network and secondary network, which provides technical support for the popularization and application of the system in Tibet.

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## 2 Integration of heating system

### 2.1 Introduction to the system

Take the heating of the office building of the energy research and demonstration center of the Tibet Autonomous Region as an example, build a solar heating system with supplementary combustion with a heating area of no less than 570m<sup>2</sup>, and the solar energy utilization rate is no less than 70%. The solar distributed heating system with supplementary combustion takes solar energy as the main heat source and gas as the auxiliary heat source. Natural gas can provide heat source support for the system when solar energy does not meet the demand. It is the best coupling mode of solar energy and gas [13,14]. At the same time, the hot water storage tank can not only solve the problem of energy peak and valley, but also reduce conventional energy consumption and protect the environment [15,16]. The working principle of the system is shown in Figure 1.



**Fig. 1** Working principle of solar distributed heating system with supplementary combustion

## 2.2 Main equipment

### a) Flat plate collector

In the solar heating system, the flat plate collector is placed at a certain angle, and the sunlight passes through the cover plate and incident on the heat absorbing plate coated with selective coating, in which the heat absorbing plate collects most of the radiant energy and converts it into heat energy. 15 large flat plates and 3 small flat plates of two thicknesses are selected for the system. The main technical parameters of large and small flat plate collectors are shown in Tables 1 and 2.

**Tab.1** Technical parameters of large flat plate collector

Parameter / Unit	Numerical value
Total area / m <sup>2</sup>	13.17
Daylighting area / m <sup>2</sup>	12.35
Heat absorber area / m <sup>2</sup>	12.37
Medium content / L	11.35
Maximum pressure / bar	10
Air drying temperature / °C	218
Geometric dimension / mm	5920*2224*135
Recommended working flow / (L·m <sup>-2</sup> ·h <sup>-1</sup> )	10-25

**Tab.2** Technical parameters of small flat plate collector

Parameter / Unit	Numerical value	
	P-G/0.6L/LM-1.84	P-G/0.6L/LM-1.76
National standard model		
Total area / m <sup>2</sup>	2	2
Daylighting area / m <sup>2</sup>	1.84	1.76
Core volume / L	1.5	1.5
Maximum pressure / MPa	0.6	0.6
Air drying temperature / °C	218	218
Geometric dimension / mm	2000*1000*80	2000*1000*120

### b) Heat storage tank

In the process of solar energy utilization, heat storage is mainly to make up for the impact of solar energy discontinuity and convert the absorbed solar radiation energy into heat energy for storage. A vertical cylindrical pressure heat storage tank is selected for the system, and its technical parameters are shown in Table 3.

**Tab.3** Technical parameters of heat storage tank

Parameter / Unit	Numerical value
Design pressure / MPa	0.33
Pressure of pressure test / MPa	0.42
Design temperature / °C	90
Volume / m <sup>3</sup>	8.5
Working medium	Water
Main material	Q245R
Product standard	GB150

### c) Wall mounted gas boiler

Two LN1GBQ50-NCN52HD condensing gas wall mounted furnaces are selected as auxiliary heat sources for the system, and their main technical parameters are shown in Table 4.

**Tab.4** Technical parameters of gas wall mounted furnace

Parameter / Unit	Numerical value
Rated voltage / V	220
Frequency / Hz	50
Rated gas pressure / Pa	2000
Rated heat output / kW	47.7
Rated condensation heat output / kW	52.3
Minimum heat output / kW	5.1
Minimum condensation heat output / kW	5.6
Rated heating heat input / kW	49.8
Minimum heating heat input / kW	5.2
Maximum heating pressure / MPa	0.3

## 3 Test data analysis

As the system is in the trial operation stage, the gas wall mounted boiler has been installed but has not been debugged, and the heat storage tank cannot be foamed and insulated due to low ambient temperature, so both are not put into operation. The commissioning started on November 1, 2017, and the preliminary heating of the system relying on the solar flat collector as a single heat source was realized on December 6. The heating effect is ideal. The radiators in each room of the office building can reach the ideal temperature during the solar energy work, and the indoor temperature of the office building is maintained at 20 °C for about 7h in the daytime (the data on December 30, 2017 are selected for analysis).

### 3.1 Solar radiation

The variation of solar radiation with time is shown in Figure 2. As can be seen from Figure 2, from 9:00 to 11:00, the solar radiation intensity increases sharply from 209 W / m<sup>2</sup> to 863 W / m<sup>2</sup>, and the average daily solar radiation intensity lasts more than 800 W / m<sup>2</sup> for nearly 6 hours.

Therefore, the unique solar radiation characteristics in Tibet provide conditions for the promotion of solar heating system with supplementary combustion in this area.

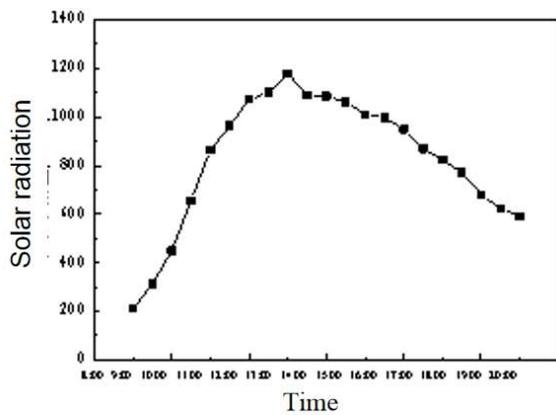


Fig. 2 Variation curve of solar radiation with time

### 3.2 Indoor and outdoor temperature

The ambient temperature has a great influence on the heat collection and heat loss of solar heating system. The changes of outdoor temperature and indoor temperature in the range of 9:00-19:00 are shown in Figure 3. Because the heat storage tank is not put into use, the change trend of indoor temperature and outdoor temperature is basically the same, and it is obviously affected by the change of outdoor temperature. If excess heat is stored, the indoor temperature change will be more stable and basically maintained in a narrow temperature range.

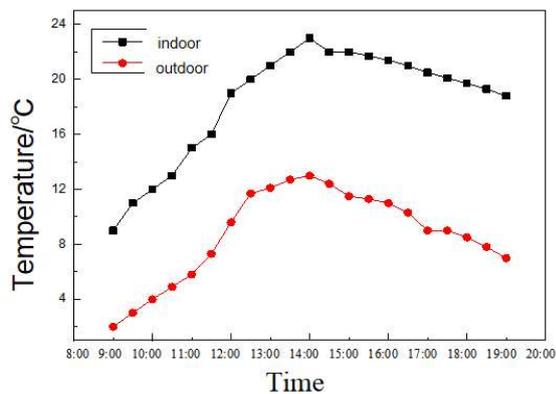


Fig. 3 Variation curve of indoor and outdoor temperature with time

### 3.3 Inlet and outlet temperature of secondary network

The variation curve of inlet and outlet temperature of secondary network with time is shown in Figure 4. During the test, the system only relies on solar energy as a single heat source for heating, so the inlet temperature of the secondary network rises slowly from 9:00 to 10:00, the temperature rises rapidly from 10:00 to 14:00 and reaches the highest value, and the temperature decreases slowly after 14:00. After 18:30, the secondary network will be

used as a heat source to heat the primary network until the secondary network is used as the end again after 9:00 the next day to absorb heat from the primary network. Compared with Fig. 3, the change curve of the inlet and outlet temperature of the secondary network with time is basically consistent with the change trend of the solar radiation with time, indicating that the magnitude of the solar radiation directly affects the inlet and outlet temperature of the secondary network.

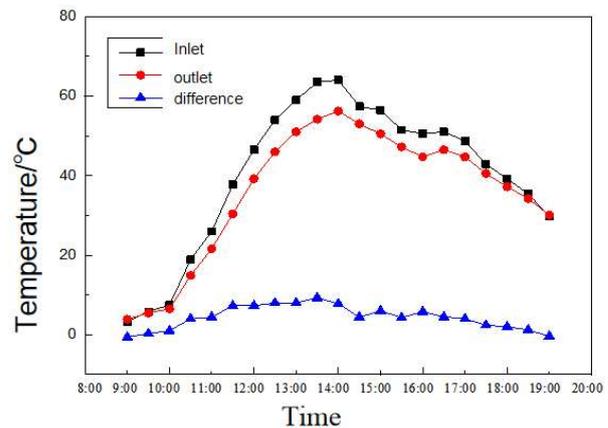
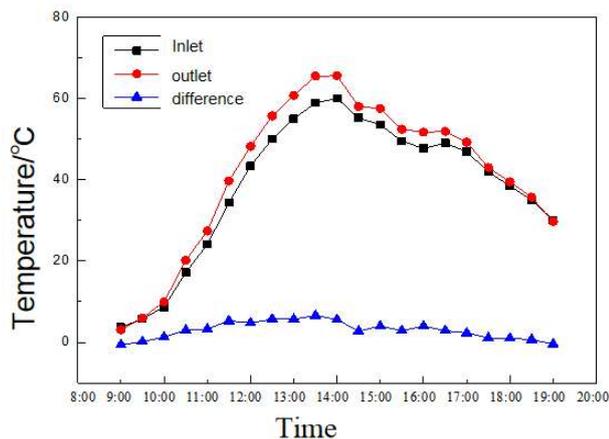


Fig. 4 Variation curve of inlet and outlet temperature of secondary network with time

### 3.4 Inlet and outlet temperature of primary network

The changes of inlet and outlet temperatures of primary network collector are shown in Figure 5. The inlet and outlet temperature of the collector is relatively high. The minimum temperature at the inlet of the collector is 3.7 °C and the maximum temperature is 60 °C; The minimum temperature at the collector outlet is 3.1 °C, and the maximum temperature is 65.6 °C. The daily average values of the inlet and outlet temperatures of the collector are higher than the outdoor ambient temperature, indicating that the collector operates at high temperature and has great heat dissipation loss, which is not beneficial to increasing the heat collection efficiency. The temperature difference between the inlet and outlet of the collector is basically maintained above 4 °C, and the maximum temperature difference is about 6.6 °C at noon. The outlet temperature of the collector is higher than the inlet temperature after 9:00, indicating that the collector absorbs sunlight radiation in the daytime and the heat collection is positive. The temperature change trend of the medium at the inlet and outlet of the collector is the same. With time, it increases first and then decreases, reaching the maximum at about 14:00. At the same time, the change trend is that it increases rapidly before 14:00, and the temperature change is stable after 14:00. The temperature difference between the inlet and outlet of the collector remains basically unchanged during operation, and its operation is in good condition.



**Fig. 5** Variation curve of inlet and outlet temperature of collector with time

## 4 Conclusion

a) According to the geographical location and solar irradiation characteristics of Tibet, the radiation absorbed by flat plate collector is measured by solar irradiator, and its variation trend with time is obtained. The results show that the solar radiation increases sharply from 9:00 to 11:00 every day, and reaches the maximum from 13:00 to 14:00. However, because the heat storage tank is not put into use, the indoor and outdoor temperature changes have the same trend, which is obviously affected by the outdoor temperature change.

b) Because the solar distributed heating system with supplementary combustion relies on solar energy as a single heat source for heating during the test, the secondary network is used as the heat source for heating the primary network after about 18:30; Until about 9:00 the next day, the secondary net is used as the end to absorb heat from the primary net. However, the system only provides heat for office buildings rather than residential buildings. If the weather is sunny, solar energy as a single heat source can meet the heating needs of users for most of the day.

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