Using of Evacuated Solar Tube Collectors for Heating in Central Yakutia Conditions

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***Abstract* — In the Department of Energy Problems of the IPTPN SB RAS an experimental stand for a solar heat supply system based on the evacuated solar tube collector was assembled. During the experiment the incident solar radiation on the collector surface and the corresponding thermal energy received from the evacuated solar tube collector were measured. Data collection began at the end of 2021 and is still ongoing. The obtained experimental data will allow to study the efficiency of the evacuated solar tube collectors in the climatic and natural conditions of Yakutsk (Central Yakutia) and measure the intensity of solar radiation. The obtained research results will make it possible to determine the effectiveness of using solar heating systems based on evacuated solar tube collectors in the conditions of Yakutia, as well as their feasibility. Features of the solar heating system operation in extremely low temperatures have been identified. Recommendations to take these features into account are given. Based on the data received the database of the solar heating system operation and the database of solar insolation were developed and registered.**

***Index Terms* — Evacuated solar tube collector, solar heating, solar radiation intensity, experimental stand, cloudiness, low temperature.**

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I. Introduction

Harsh climatic conditions, remoteness of populated areas, and complex transport schemes impose significant restrictions on the development directions of the Sakha Republic (Yakutia) in general and energy supply in particular. The current situation in the heat supply sector of the Republic is characterized by serious problems: low technical level, low economic efficiency of heat supply facilities and high fuel costs [1]. On average the duration of the heating season in Yakutia is 8-9 months a year and in some settlements of the Arctic zone it is almost all year round. Due to the influence of climate the amount of energy for heating 1 sq. meter of housing is required two times more than the average for the Russian Federation and accordingly economically justified tariffs for utilities significantly exceed their average Russian level [2].

Expenditures from the state budget of the Sakha Republic to provide subsidies to organizations in the public utility complex are growing every year. On average for the period from 2015 to 2018 90.8% of the economically justified tariff for heat energy is subsidized from the regional budget. Accordingly, the part of the economically justified tariff paid by the population was 9.2%. Subsidies for heat energy only in the Arctic zone were 5.7 billion roubles [3].

In the current situation of high costs for heat supply to hard-to-reach settlements of the Republic huge potential for the introduction of energy-saving technologies is created. Hybrid solar heating with vacuum solar collectors is a promising technology for implementation due to the presence of significant natural heliopotential. The long-term average of photovoltaic power potential at some solar power plants in Yakutia, in particular in the settlements of Dulgalakh, Batamai, Yuchyugey reaches 1000-1100 kWh/kW per year, and on average more than 800 kWh/kW per year for all solar power plants of the Sakha Republic

TABLE 1. Solar power plants characteristics

Settlement	POWER, KW	Long-term average of photovoltaic power potential at year, kWh/kW
Batagay	1000	833
Kybergene	20	1023
Batamai	60	1009
Yunkyur	40	836
Yuchyugey	30	1181
Orto-Balagan	50	909
Dulgalakh	20	1051
Kudu-Kyuyol	20	920

Fig. 1. Solar collector, pyranometer.

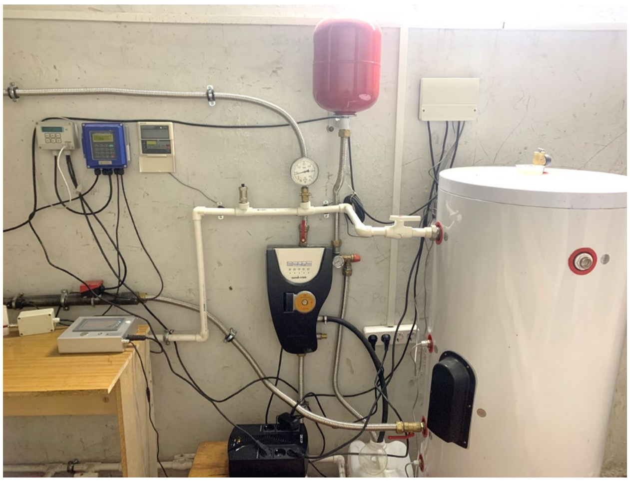

Fig. 2. Measuring stand.

[4]. The long-term averages of photovoltaic power potential of several solar plants located in different parts of the Sakha Republic are shown in Table 1. For more efficient operation, such systems include thermal energy storage tanks that store it for further use at night time. The economic success of installing solar heating can be ensured by a combination of two main factors: high costs for heating and the availability of a significant amount of solar energy.

II. EXPERIMENTAL STAND

Studies of the working processes of a solar heat supply system based on a evacuated solar tube collector were carried out under natural conditions in Yakutsk at a specialized stand of the Department of Energy Problems of the IPTPN SB RAS. The experimental stand allows monitoring the operating parameters of a solar heating system and solar radiation falling on the ground for a long time. Measuring the resulting useful thermal energy using an ultrasonic heat meter allows you to evaluate the efficiency of the solar collector depending on climatic conditions (Figures 1-2).

The experimental stand is installed on the roof of the IPTPN SB RAS main building in Yakutsk. Thermal energy source is an evacuated solar tube collector SILA R5-15 with 15 tubes. The total collector area is 2.41 m2, the aperture area is 1.64 m2. The collector is installed at a height of 22 meters from the ground surface. The azimuth angle corresponds to the location of the roof of the building and is equal to 217°, the angle of inclination to the horizon is 65°, the roof slope is 10°. The system is divided into two separate circuits. Solar circuit with antifreeze liquid (ethylene glycol) and heating circuit with rainwater as a liquid. Heat exchange takes place in a storage tank with a volume of 200 liters with one heat exchanger. The useful thermal energy received from the collector is measured using the SPT940 heat meter with a stationary ultrasonic flow meter Streamlux SLS-720F. The heat meter records the temperature data of the supply and return pipelines, the volume and mass flow of the liquid. The amount of incoming solar radiation on the collector surface is measured using a RK200-04 pyranometer. The experimental stand scheme is shown in Figure 3.

III. DATABASES

Based on the data obtained, as well as open sources of information on the climatic characteristics of the region, a database of useful thermal energy of a solar heating system with an evacuated solar tube collector with 15 heat pipes was compiled. At the beginning of the experiment until September 2022 indications were read off for a collector with 11 operating tubes, after September 2022 the experimental stand operated at full capacity. The amount of incoming solar radiation on the collector surface was recorded with a measurement period of 5 minutes. To carry out calculations of the system efficiency these parameters of climatic conditions were added to the database according to the meteorological station of the Yakutsk airport: ambient temperature, atmospheric pressure, relative humidity, wind speed and total cloudiness. Software was created to process the large amount of data obtained from the pyranometer and heat meter. This program received a certificate of state registration of the computer program №2023669993 [4]. State registration of the database №2022622548 of total solar radiation using a pyranometer installed on the roof of the IPTPN SB RAS main building was also completed [5]. The difference between the developed database is the frequency of measurements of 5 minutes in contrast with the data from weather stations in Yakutsk with a measurement period of 3 hours and data from satellite actinometric measurement systems with a measurement period of 1 hour.

IV. Installation Features and Operating Experience

Additional difficulties arise in the design and installation of equipment on inclined surfaces, in the manufacture of the frame and in fine-tuning the angle of inclination of the collector. It is best to provide a mechanism for smoothly adjusting the angle of the frame or, if possible, install the equipment on a flat surface.

Flexible, cold-resistant wires should be used to transfer pyranometer data. The braid of conventional wires breaks in severe cold even with a slight change in the position of the wire.

The measuring equipment is located in the utility room under the roof, the length of the pipe branch is about 15 meters which is quite a lot. The length of the solar collector circuit should be minimized to reduce heat loss in the pipe, the load on the circulation pump, the volume of expensive antifreeze used and save material.

When designing an installation special attention should be paid to the correct selection of the storage tank volume. Excessive volume of the storage tank leads to inefficient operation of the entire system; insufficient volume will lead to boiling of the antifreeze liquid in the solar collector circuit. It is also very important to take into account the operating mode of the circulation pump in the solar collector circuit, the length of the solar collector circuit, the characteristics of the heat exchanger of the storage tank and the solar collector.

During the operation of the stand, it was revealed that it is better to place the expansion tank of the solar collector circuit directly at the entrance to the solar collector. In case of circulation pump failure incorrect settings of the circulation pump, interruptions in the power supply without backup, the antifreeze liquid in the solar collector

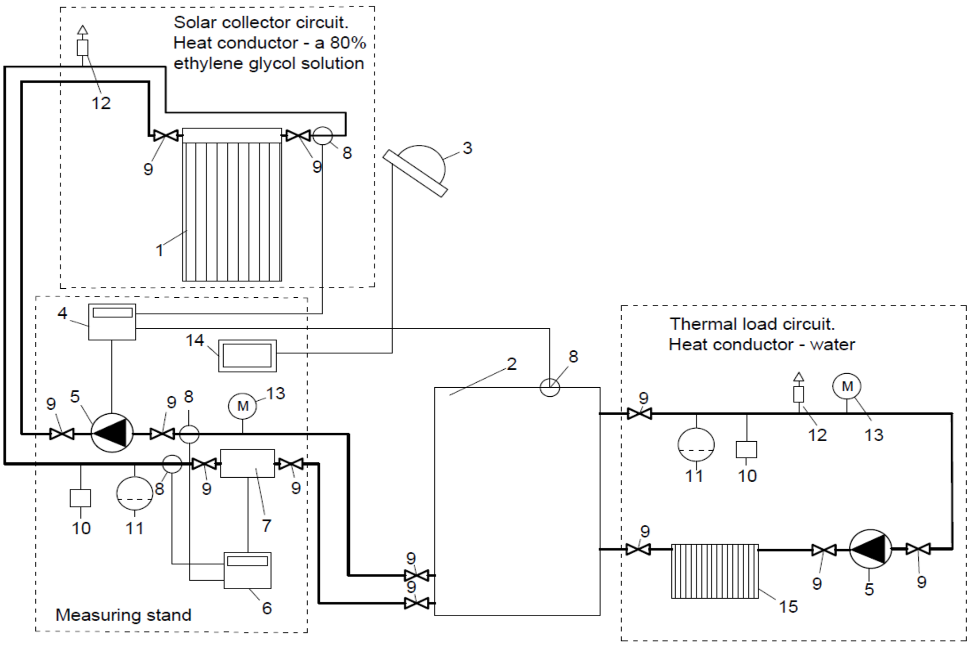

Fig. 3. Scheme of the experimental stand.
1 – evacuated solar tube collector; 2 – storage tank; 3 – pyranometer; 4 – controller; 5 – pump; 6 – heat meter; 7 – flow meter; 8 – temperature sensor; 9 – ball valve; 10 – dump valve; 11 – expansion tank; 12 – air vent; 13 – pressure gauge; 14 – data logger; 15 – heating radiator.

circuit quickly heats up which causes its release into the atmosphere in the presence of an emergency coolant discharge valve. Without valve the system will overheat which can lead to operational incident.

During the night with high humidity especially if sewer pipes or ventilation are located nearby frost forms on the collector tubes which interfere with the heat exchange process. After sunrise with sufficient intensity of solar radiation the frost melts and collector begin to operate normally.

There is an assumption that a system with a storage tank for heat exchange fluid directly on the top of a solar collector will work better due to the inertia of the heat transfer process from the heat exchange fluid of the solar collector circuit to the water in a tank.

V. CONCLUSION

Evacuated solar tube collectors have shown positive results when operating in low temperature conditions subject to certain requirements. When designing the installation it is necessary to minimize the length of the solar collector circuit, provide expansion tanks and an emergency coolant discharge valve, and pay special attention to the correct choice of the volume of the storage tank. It is also very important to take into account the operating mode of the circulation pump in the solar collector circuit, taking into account the length of the solar collector circuit, the characteristics of the heat exchanger of the storage tank and the solar collector. During the operation of the stand, it was revealed that it is better to place the expansion tank of the solar collector circuit directly at the entrance to the solar collector. During the winter season, frost forms on the surface of the vacuum manifold tubes, which reduces the efficiency of the manifold.

Evacuated solar tube collectors have shown positive results when operating in low temperature conditions, subject to certain requirements. When designing the installation, it is necessary to minimize the length of the solar collector circuit, provide expansion tanks and an emergency coolant discharge valve, and pay special attention to the correct choice of the volume of the storage tank. Setting the operating mode of the circulation pump in the solar collector circuit should be done taking into account the length of the solar collector circuit, the characteristics of the heat exchanger, storage tank and the solar collector. The solar circuit expansion tank must be installed directly at the entrance to the solar collector. During the winter season, frost forms on the surface of the vacuum manifold tubes, which reduces the efficiency of the manifold.

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