Evaluation Of The Efficiency Of The Vacuum Solar Collector In Cloudy Weather Conditions

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ABSTRACT

Evaluation of the efficiency and calculation of the vacuum solar collector's operation under cloudy weather conditions for the city of Tashkent has been completed

Keywords: solar heating, flat collector, vacuum collector, battery, efficiency

Introduction. Calculation of solar system collectors should be performed separately for each specific case, as hot water consumption and building heating needs depend on a multitude of various factors.

The simplest and equally effective method for calculating the reference amount of energy received from a solar collector in a given region is the method based on the use of data on the average annual solar activity in that area and the absorption area of the device. To assess the completeness of the solar collector's heat energy supply, we use statistical data.

Thus, on average, one household requires 2-4 kW of energy per person per day to heat hot water.

The volumes of energy generated by the solar collector directly depend on several parameters, including:

1) the level of solar insulation in the device's operating region;
2) device absorption area;
3) Collector efficiency;
4) panel inclination angle to solar radiation.

Therefore, evaluating the efficiency and calculating the operation of a vacuum solar collector in cloudy weather conditions, for example, for the city of Tashkent.

The main heating element of the solar collector is a vacuum tube with selective coating. In simple thermosifonic collectors, the water heating process occurs directly in the tube itself (*Fig.1*). Due to the phenomenon of convection, heated water moves upwards, while cold water moves downwards.

The zero heat conductivity of the vacuum between the inner and outer tubes ensures heat conservation. The efficiency of such a system is highest in the warm season. Thus, in one sunny August day, a thermosiphon water heater heats 200 liters of water to 84°C.

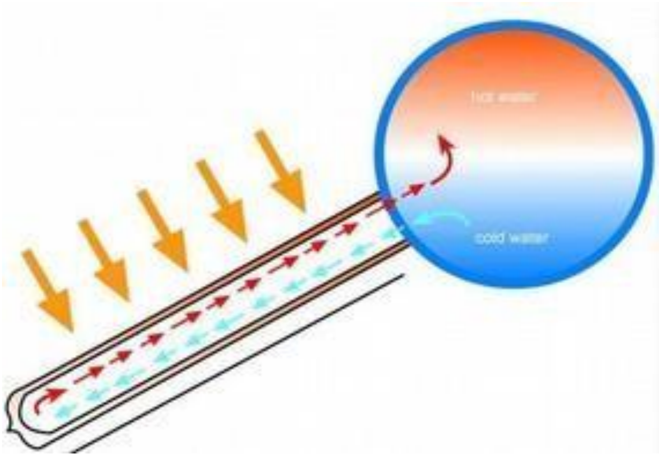

Fig.1. Vacuum tube with selective coating.

The flawless effectiveness of a thermosiphon water heater during the warm season becomes a problem in the cold: despite the 50 mm insulation of the storage tank, heat loss during the cold night can reach 20-25°C. If the frost persists for several days, and the sun cannot penetrate through the dense layer of clouds, the water in the tubes turns into ice, which can lead to the rupture of the inner tube and the failure of the entire collector. Additionally, replacing even one tube requires draining all the water in the tank, which is a very labor-intensive process.

The purpose of the work is to analyze, evaluate, and calculate the performance of a vacuum solar collector under cloudy weather conditions.

Research Methods. To calculate the efficiency of a solar vacuum collector for hot water supply, the following calculation method can be used:

1) It will be necessary to determine how many degrees the water temperature and its volume should increase. For example, we can take a private house with residents consisting of 5 people (2 adults and 3 children). On average, 50 liters of water is consumed per person per day (KMK 2.04.01-98 Internal Water Supply and Sewerage of Buildings). Accordingly, 50 * 5 = 250 l. The average temperature of tap water is +15°C during the summer period and +5°C during the winter period (KMK 2.04.07-99). It must be heated to 50°C. 50-15=35°C for HWC.

Accordingly, we need to calculate for the winter period of time, taking into account the system up to 50°C. 50-5=45°C.

2) It is necessary to determine the amount of energy to heat the required volume of water. To heat one liter of water by one degree, you need to expend 1 kcal of energy. 250 l•35°C = 8750 kcal. To convert this energy to kWh, we use the following formula:

8750 / 859.8 = 10.17 kWh (1 kWh = 859.8 kcal)

3) It is necessary to determine the amount of energy that the solar collector can convert into heat. A variant of the location of the solar installation in the city of Tashkent is proposed for consideration. The value of solar radiation on a surface inclined to the horizon by 41.3°C with a southward orientation, according to KMK 2.04.16-2018 "Solar Hot Water Supply Installations":

1) the daily sum of solar radiation per horizontal area during the hottest month - July - is $E_{mountain}$= 27.13 MJ/ (m^2•day),

2) the daily sum of solar radiation - for the horizontal area in the coldest month - in December Egor= 5.4 MJ/ (m^2•day).

Taking into account that 1 kW·h = 103 W•3600 s = 3.6 MJ, we convert our coefficients to kW•h/day and obtain: in July for 1 m^2 E_{hor}= 4.83 kW•h/day, and in December E_{hor}=0.83 kW•h/day.

The efficiency of a vacuum solar collector is generally assumed to be 80%, but this is not entirely accurate, as the efficiency of vacuum collectors is influenced by many factors:

1. Dependence on the temperature difference between the absorber and the environment.
2. Solar radiation intensity.
3. It depends on the angle of inclination of the tubes and the latitude of the terrain.

For preliminary calculations, we can assume that the value of absorbed energy transfer by vacuum tubes is equal to 4.83•0.8 = 3.86 kWh/day of the collector's absorption area for the month of July. The value of absorbed energy transfer by vacuum tubes is 0.83 x 0.8 = 0.66 kWh/day of the collector's absorption area for December.

The absorption area of a 58 mm diameter and 1800 mm length vacuum tube is 0.327m2. Because S = 2πLR or through the diameter

$$S = \pi D L = 3.14*0.058*1.8 = 0.327 m^2.$$

Taking into account that the tube is illuminated by the sun not from all sides, but only half S = DL=0.058*1.8=0.104 m^2

It is not difficult to calculate that one tube is capable of receiving and transmitting 1.262 kWh and 0.215 kWh of solar heat, respectively, in July and December.

4. It is necessary to determine the required number of tubes. For this, using the value calculated above, we determine the number of tubes that need to be installed. The energy required to heat the required amount of water is 10.17 kWh. The energy that a single vacuum tube can transmit, depending on the month, is 1.262 kWh and 0.215 kWh.

July - 10.17 / 1.262 = 8 tubes. December - 10.17 / 0.215 = 47 tubes.

The optimal choice will be two 25-tube collectors and a 275-liter tank (250+10%=275) with a single heat exchanger.

For clarity, let's present a table of the efficiency of a 50-tube collector field oriented south.

The angle of inclination of the tubes to the horizon is 45°, expressed in kWh per day of thermal energy, based on the data of KMK 2.06.16-2018, we obtain the following graph (Fig. 2).

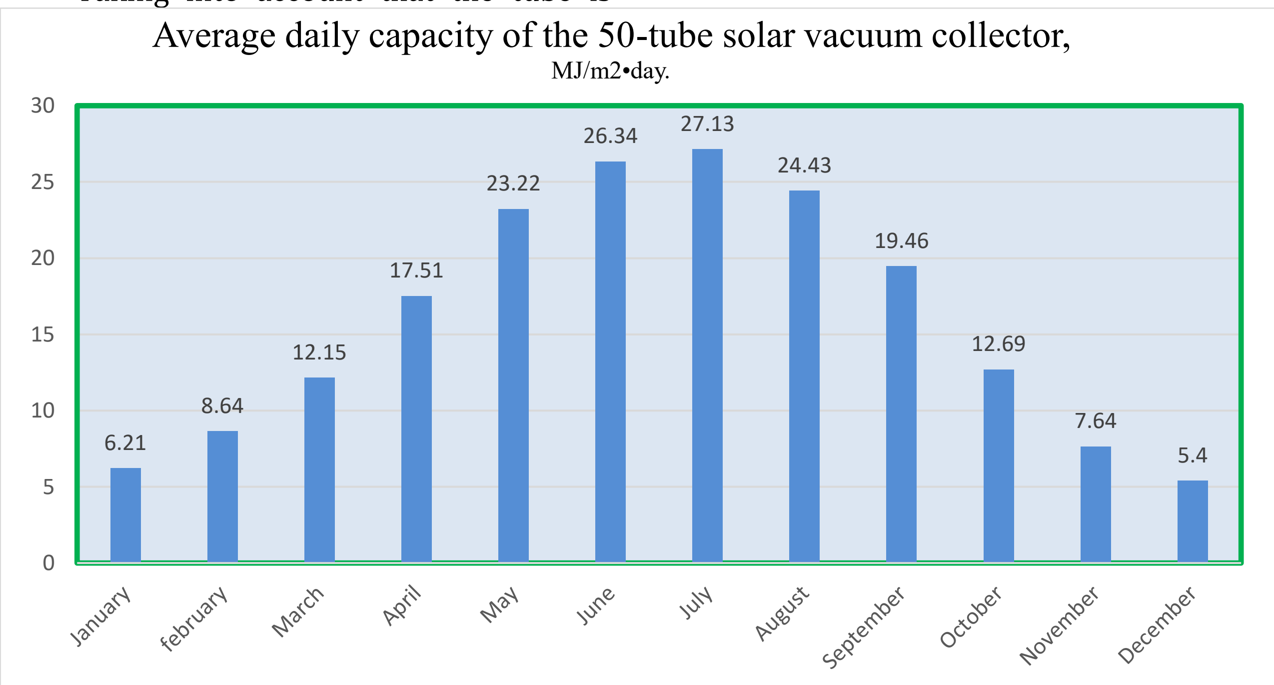

Figure 2. Average daily capacity of the 50-tube solar vacuum collector, MJ/m2•day.

For these figures to take on a practical significance, let's calculate for what temperature in the storage tank we can calculate.

Let's take, for example, a recommended tank for 275 liters.

The water temperature in the tank at the beginning of the day is equal to the temperature in the boiler room, where it is approximately 20°C.

First, we convert kWh to kilocalories: In this case, the boiler's power in kcal is: 0.215*859.8*50=9242.85 kcal. (10.7 kW)

Now, let's determine how many degrees the proposed collector can heat the water in the tank during one average day in December:

- P- collector capacity, in kcal.
- V- water volume in the tank: 275 l (0.275 m^3).
- Δt is the desired value (the value of the temperature at which the water in the tank will be heated per day).

$$At = P/V$$

Even if you make good thermal insulation of the heat line, you can lose some of the heat on the way to the tank. The tank itself may not even have 100% thermal insulation. Similarly, the heat exchange process between the end of the copper tube inside the solar collector with the heat carrier and the heat exchange in the coil of the boiler reduces the overall efficiency of the system. In this case, we can calculate another 10% for winter, 5% for November and March, 2% for April and October, and in summer, we can take this type of loss as zero and then we get:

$$\Delta t = P/V*0.9$$

$$\Delta t_{dec} = 9242.85/275*0.9 = 30°C$$

This means that on average for December we will get such a value Δt. Now we need to try to understand what this average means: According to the portal: https://pogoda.365c.ru/uzbekistan/tashkent/po_mesyacam, sunny days in Tashkent in December 52%, cloudy 38%, cloudy: 10%

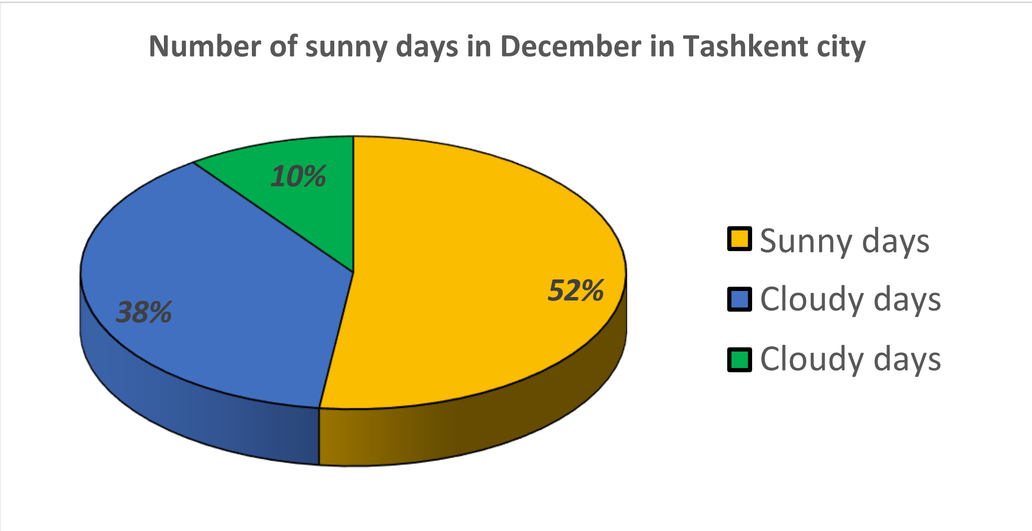

Figure 3. Diagram of the number of sunny days in December in Tashkent city

Results. Thus, we have an average value Δt=30°C. This means that on average, in December, we get 58oC in the tank in one day. Without considering the tank losses we discussed above. But two consecutive cloudy days are enough for the water in the tank to cool to ambient temperature. At the same time, in two sunny days, we will see 60-70 degrees on the tank's thermometer, if there is no discrepancy. The higher the difference between the temperature in the tank and the air in the boiler room, the more intensive the heat exchange.

The solar collector operates in winter, but we cannot consider it the only source of heat. Only as a help to the main source.

On average, using a solar collector can save:

- During the winter period, 20 to 40% of the energy is used for heating and HVS.
- Between April and October, the need for heating is significantly lower, and the sun is more abundant, i.e., 60-70% for heating and up to 90% for GHS.
- From May to September, there is a lot of sunshine, there is no need for heating, so you can 100% close your GHS needs here!

It is known that if the calculation for July remains practically unchanged, then for February it is necessary to take into account losses of at least 10%. Then the values will look like this:

July - 8.14 / 0.4075 = 20 tubes.

December - 8.14 / (0.130*0.9) = 70 tubes.

Conclusion. Based on the calculations, it will be recommended to install a collector with 20 and 30 tubes connected to a group of 50 tubes, as well as a tubular electric heater, and a 2kW storage tank. Excess heat in summer can be resolved as follows, if there is a pool - the pool is heated, if there is no pool - you can use a heat fan that operates on the principle of a furnace in a car. The heat release can be controlled automatically by the solar system controller. The controller, circulation pumps of the solar system, and heat exchanger operate from a 220V 50Hz network. If the power supply is disconnected on a sunny summer day and the circulation of the heat carrier stops, the temperature in the collector will reach its limit values within seconds. This can lead to an accident and expensive equipment repairs. Therefore, the correct solution will be to ensure their uninterrupted power supply, consisting of a small inverter with a charger and a battery-based gel battery.

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