Analysis of Heat Transfer of Solar Water Collectors

Sattorov Alimardon Hamdamalievich, Husanov Nurmuhammad
Ferghana Polytechnic Institute, Ferghana, Uzbekistan

ABSTRACT

This article provides recommendations for the provision of solar water, hot water to residential buildings, industrial, utilities and agricultural facilities using an air collector. In particular, the article is devoted to topical issues of the study of water heating systems based on solar air heaters and hot water supplies.

KEYWORDS: *Solar air collector, absorber, temperature, convective heat flux, pipe, Reynolds number, laminar, turbulent*

Today, more and more attention is paid to the use of energy-saving sources, which is a modern requirement for the development of modern solar water heaters using solar energy with high efficiency. [1,2] The easiest way to convert sunlight into thermal energy is to use solar air heaters. These types of heaters are cheaper than other types of heaters and solar heaters are widely used due to the simplicity of the design of the device. [3.4]

About 20% of the energy consumed from unconventional energy sources in the world, and up to 30% of all fossil fuels produced is used for the needs of solar systems. Therefore, the implementation of a set of measures to solve the problems of energy conservation and the development of the use of non-traditional renewable energy sources is an urgent task. [5]

Given the shortage of fuel and the constantly rising prices, the development of huge sources of solar energy is one of the most important scientific and technological challenges. [6]

Each solar collector is a special piece of solar technology. This system can be used for the production of hot water and then for other services. The main difference between solar collectors and other similar technologies are the possibility of using renewable energy sources in industrial infrastructure. [7]

Areas of use:

1. Hot water supply of residential, industrial and public buildings.

2. Application in the home heating system.

2. Connection to the existing heating system of the house**.**

The principle of operation of the collector in the heating system of the house

If the water in the lower part of the collector is warmer than in the upper one, heating is switched on. Water is pumped through the system. The water in the tank is heated by heat exchange, usually the collectors are heated to a certain temperature. As a result, cold water and hot water alternate.

Due to the expansion of hot water, the exchange of liquid in the system occurs due to a natural circulation process. When water heats up, it rises, and cold water - vice versa. For the system to work properly, the thickness of the thermal insulation layer should be 25-30 cm.

As for the tank, it must be rectangular. If these conditions are met, the water is evenly distributed over all parts. Thus, the system can work almost completely. The use of solar collectors in a home heating system can reduce costs by 50-90% if the collectors are installed correctly.

In spring and autumn, the system is very active, but designed to work in all weather conditions. The main parameters to consider when choosing a collector are: the area occupied by the solar system, the amount of thermal energy. If the system is used in winter, the parameters are taken into account. Because in winter, heating a house requires more energy and costs. [8]

Solar collectors are mainly used as an additional source. If the thermal insulation of the building is installed correctly, this solar system can be used autonomously. Natural circulation of water due to convection flow is one of the principles of this solar system.

Due to the passive circulation of water, this route is less profitable than others. Auxiliary electric circulation pumps are used in forced circulation systems. In this case, collectors are very useful. But the demand for timely service will increase, because everything will depend on electricity. [9]

Connecting the collector to the existing home heating system.

Depending on what kind of circulation is used in the system, the connection to the existing heating system of the house is determined. Connecting to natural circulation water is one of the easiest ways. In this case, one of the basic principles will be the heating of water in the heating system itself. [10]

Therefore, such systems are much cheaper than systems that use pumps. It is possible to connect the collector to the forced circulation system using automation. These systems have a clear advantage: the controller controls the pump using special sensors.

These sensors stop heating when the temperature rises to the set temperature. The tank, water return point and collector outlet are the main places where such sensors are installed.

It is desirable to use additional heat sources in conjunction with such systems. Examples are gas heating and fuel heating. In such cases, the water temperature can vary depending on the location of the collector in relation to the sun. It is best to install the collector from the beginning in a location where the sun shines directly during the main part of the day. Calculating how much space is needed for a particular collector is a little difficult.

In this case, it is necessary to take into account not only the type of roof, but also the size of the tank, as well as the radioactivity of the sun in the region. Therefore, it is convenient and expedient to install everything in agreement with experienced professionals[20-26].

Heat transfer and hydraulic resistance in conditions of fluid movement in a pipe. The cross-section of the liquid flow in the pipe is viscous or laminar if the condition Re <Recr is satisfied and there is no free convection in the forced flow[11]. The calculation of heat transfer in the flow of a viscous liquid (gas) in straight round pipes are carried out according to the following equations:

a) If the wall temperature does not change or changes little along the length,

$$\overline{N}_u = 1{,}55\left(\frac{1}{P_e}\frac{\ell}{d}\right)^{-\frac{1}{3}} E_1\psi_1 \qquad (1)$$

here 1 / P_e · l / d≤0.05 when $\frac{1}{P_e}\cdot\frac{\ell}{d} \le 0{,}05$ when

$$\overline{N}_u = \left[3{,}66 + \frac{0{,}0668 P_e\frac{d}{\ell}}{1+0{,}04\left(P_e\frac{d}{\ell}\right)^{\frac{2}{3}}}\right] E_1\psi_1 \qquad (2)$$

Here $\frac{1}{P_e}\cdot\frac{\ell}{d} \le 0{,}004$

б) If the heat flux density in the wall does not change,

$$N_u = 1{,}31\left(\frac{1}{P_e}\frac{x}{d}\right)^{-\frac{1}{3}}\left(1+2\frac{1}{P_e}\frac{x}{d}\right)E_2\psi_2 \qquad (3)$$

Here $\frac{1}{P_e}\frac{x}{d} \leq 0{,}04$;

$$N_u = \left[4{,}36 + \frac{0{,}263}{\left(\frac{1}{P_e}\frac{x}{d}\right)506\cdot\exp\left(41\frac{1}{P_e}\frac{x}{d}\right)}\right]E_2\psi_2 \qquad (4)$$

Here $\frac{1}{P_e}\frac{x}{d} \geq 0{,}001$

E1 and E2 in the equations are the hydrodynamic start point corrections.

In the leading (parabolic) velocity profile in the opposite section of the heating or cooling pipe, that is, in the damping section, E1 = E2 = 1 For 1 / R_e 1 / d <0.1 for the absence of a damping part and with a uniform distribution of speed at the inlet:

$$E_1 = 0{,}6\left(\frac{1}{R_e}\frac{\ell}{d}\right)^{-\frac{1}{7}}\left(1+2{,}5\frac{1}{R_e}\frac{\ell}{d}\right); \qquad (5)$$

$10^{-4} \leq \frac{1}{R_e}\frac{x}{d} \leq 0{,}064$ for values:

$$E_2 = 0{,}35\left(\frac{1}{R_e}\frac{x}{d}\right)^{-\frac{1}{6}}\left[1+2{,}85\left(\frac{1}{R_e}\frac{x}{d}\right)^{0{,}42}\right] \qquad (6)$$

(5,6) The equations give the following

$$\overline{N}_u = \frac{\overline{\alpha} d}{\lambda};\ N_u = \frac{\alpha d}{\lambda};\ P_e = \frac{\overline{w} d}{\alpha}; R_e = \frac{\overline{w} d}{\upsilon} \qquad (7)$$

$\alpha = \frac{q_c}{\Delta t_\lambda} - x = 0$ average heat transfer coefficient in the pipe section from

$x = 1$; qc - average heat flux in the same section;

Δtl - mean logarithmic temperature pressure; a = qc / Δt is the local heat transfer coefficient at a distance x from the inlet; qc and Δt - local temperature pressure; d - pipe diameter; w is the average fluid velocity in the section. Physical parameters of liquid or gas (1,2) (λ, α, υ) temperature in equations.

$$\Delta t_r = t_c \pm 1/2\overline{\Delta} t_l$$

("+" For cooling the liquid, "-" for heating the liquid); in equations at temperature

$$t_j = \frac{1}{2}\left(t_{j1} + t_{j2}\right)$$

The temperature in the equation:

$t_r = \frac{1}{2}(t_c + t)$ when

The temperature in the equation $t_j = \frac{1}{2}\left(t_{j1} + t_{j2}\right)$ when

In the equation (6) at the average mass temperature of the liquid.

t- (distance x from input) is selected.

The influence of variable physical properties is taken into account using the coefficients ψ1 end ψ2

For dripping liquids under conditions of a sharp change in viscosity along the flow section:

$\psi_1 = (\frac{\mu_c}{\mu_j})^{-0,14}$(where mc / mj ranges from 0.07 to 1500)

$\psi_1 = (\frac{\mu_c}{\mu_j})^{-1/6}$(with mc / mc from 0.04 to 10)

where μcva μj are the dynamic coefficients of viscosity at the wall temperature and the average mass temperature of the liquid.

In the hydrodynamic initial part, the velocity profile changes along the length from the inlet section to the full development of the velocity profile[21-33]

The steady-state flow velocity profile remains fully developed, i.e. does not change in length (if the properties of the liquid do not change).

Conclusion. Solar water and air collectors save energy used for heating and hot water supply. An analyses of the design of solar water-air collectors shows that such a device provides residential buildings, industrial, household and agricultural facilities with hot water. A unique feature of solar water and air collectors are the use of advanced technologies and energy-efficient materials in the production. New solar water heaters are a new stage of work carried out in the Republic of Uzbekistan to improve energy efficiency and the widespread use of alternative energy sources.

The solar water available in this article can save 15-20% of the energy used when heating water through air collectors. In addition, the efficiency of the collector can be increased by 10-15% without changing the amount of energy consumed to compared to existing local solar water heaters.

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