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Determination of the heat capacity of a curved solar water collector

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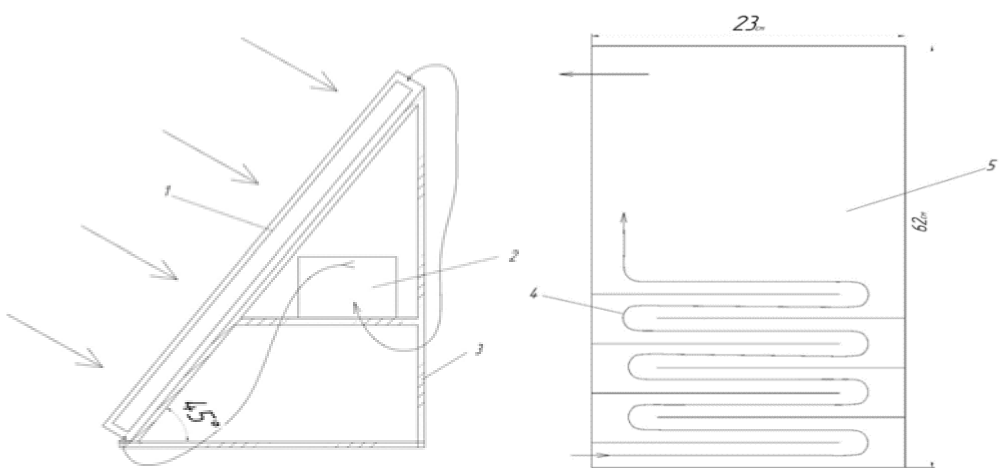
Abstract
The brief information about the article: This article discusses the ways of determining the heat capacity of a curved solar water collector, alternative operating solutions for a solar collector, and increasing their efficiency by accelerating heat exchange.

Keywords: Solar water heaters, heat efficiency, collector, pipe, water movement, heat exchange

Introduction
Heating and hot water supply systems are serves to heating system of buildings and provide with needed demand for hot water. In order to heat the rooms in winter and create a comfortable environment, the heating system must work with the necessary parameters.
In developing a method for calculating the heat capacity of a solar collector, an analaysis performed for a design consisting of round –section surface tubes.
For example, consider the laminar flow of a liquid flowing through a pipe with a circular cross – section. This trend was first studied by the scientist Puazel. It should also be mentioned that the heated water in the water collectors moves under the natural convection conditions and water velocity is much lower. As a consequence of this, the thermal processes inside the collector pipes are low intensity, and in general, the heat capacity of the collector become insufficient. In order to solve this problem, the collector pipes are prepared curved. When water moves in curved pipes, the centrifugal force acts on the water particles, resulting the frequent changes in the velocity of the water, which simplifies the process of heat exchange. In addition to this, the heat exchange surface of the curved pipe is larger than that of a simple straight pipe, so that means, the heat capacity of the collector can be increased. In order to test this hypothesis, the results of theoretical research will be presented in this article. Since the water movement of the collector is small, we assume the development of the Puazel type of water movement inside the curved pipe. According to this hypothesis, the velocity diagrams of the water flow on each section of the pipe are formed in the form of a parabola. The forces of natural gravity is found as follows.



1. – Picture Appearance of a curved collector
1 – Flat solar water collector; 2 – bac – accumulator; 3 – wooden frame;
4 – Serpentine tube; 5 – the bottom of the collector

$$\Delta P = h*g*(\rho_1 - \rho_2) \quad (1)$$

These forces, in turn, are applied to the resistance in the pipe according to the Darcy - Veysbach formula.

$$\Delta P = (64/Re)*(\rho\omega^2/2)*(l/d) = (64*\nu/\omega d)*(\rho\omega^2/2)*(l/d) = (32/d^2)*(\omega*\rho*l*\nu) \quad (2)$$

As a result of this, the velocity of the water can be found

$$\omega = h*g*(\rho_1 - \rho_2)*d^2/32*\rho*l*\nu \quad (3)$$

Then the water consumption of the collector is found as follows

$$G = \omega * S * \rho_{sr} \quad (4)$$

After that the heat capacity of the collector can be found

$$Q = \omega * S * \rho_{sr} * \Delta t \quad (5)$$

The length of the curved pipe is 4 meters, the inner diameter is 4 or 2 millimeters and the outer diameter is 6 millimeters. As a result of the light radiation of the sun falling on the half surface of the curved tube, the tube absorbs the following amount of heat energy.

400 x3,14x0,006x4/2 = 15 vt

Here the average solar radiation is taken as 400 vt/ m^2.
The cross – sectional area of a curved pipe is the same to

$$S = \pi * \frac{d^2}{4} = 3{,}14 * \frac{0{,}0042^2}{4} = 0{,}0014\ m^2$$

The average density of water

$$\rho_{o'tr} = (\rho^1 + \rho^{11})\frac{1}{2}$$

$$\rho^1 = 998{,}6\frac{kg}{m^3}, \rho^{11} = 998\ kg/m^3$$

$\rho_{o'tr}$= (998,6 +998)/2 =998,3kg/m^3

It must be noted that the water in the curved pipe is heated to 2 degrees in a single cycle. We determine the velocity of water by Puazel`s formula.

$$\omega = h*g*(\rho_1 - \rho_2)*d^2/32*\rho*l*\nu = [0{,}65x9{,}81x(998{,}6 - 998{,}0)x(0{,}0042)^2]/(32x998{,}3x4x0{,}910^{-6} = 0{,}06\frac{m}{s}$$

The water consumption can be determined as follows,

$$G = \omega * S * \rho_{sr} = 0{,}06x0{,}0014x998{,}3 = 0{,}08\frac{kg}{s}.$$

We may find the heat capacity of the collector as follow,

$$Q = \omega * S * \rho_{sr} * \Delta t = Gx\Delta txS_r = 0{,}08x2x4{,}18 = 0{,}67\ kvt = 670\ vt$$

We perform such calculations at 3, 4 and 5 degrees.
For 3 degrees we use

$$Q = \omega * S * \rho_{sr} * \Delta t = Gx\Delta txS_r = 0{,}09x3x4{,}18 = 1{,}13\ kvt.$$

and for 4 degrees

$$Q = \omega * S * \rho_{sr} * \Delta t = Gx\Delta txS_r = 0{,}1x4x4{,}18 = 1{,}67\ kvt$$

formula is used.

Then for 5 degrees we may use

$$Q = \omega * S * \rho_{sr} * \Delta t = Gx\Delta txS_r = 0{,}12x5x4{,}18 = 2{,}5\ kvt$$

Based on the theoretical analysis and calculations, the graphs of relationship between water consumption in the solar collector and the inlet and outlet temperatures are made. Furthermore the difference between the thermal efficiency of the solar collector and the inlet and outlet water temperatures are plotted. The technical capabilities of solar water collectors can be assessed according to the following schedule.

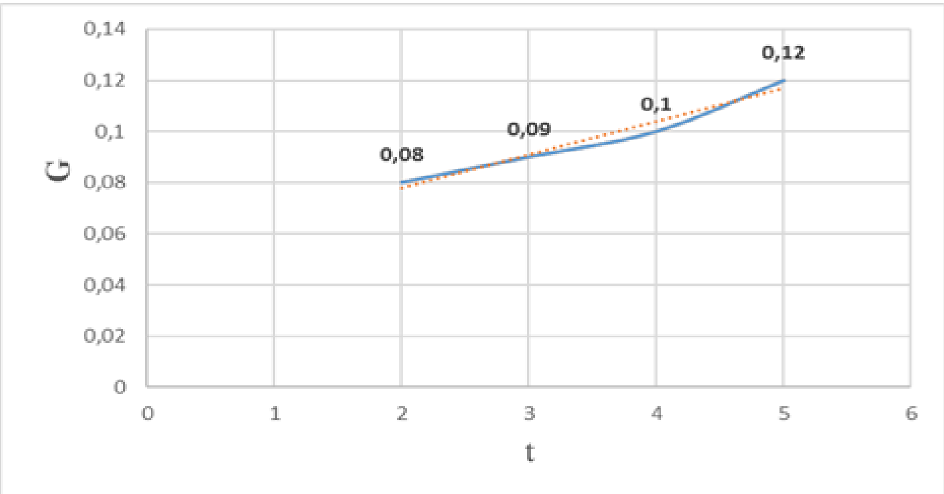


Fig 2: The relationship between water consumption in a solar collector and the difference between inlet and outlet water temperatures

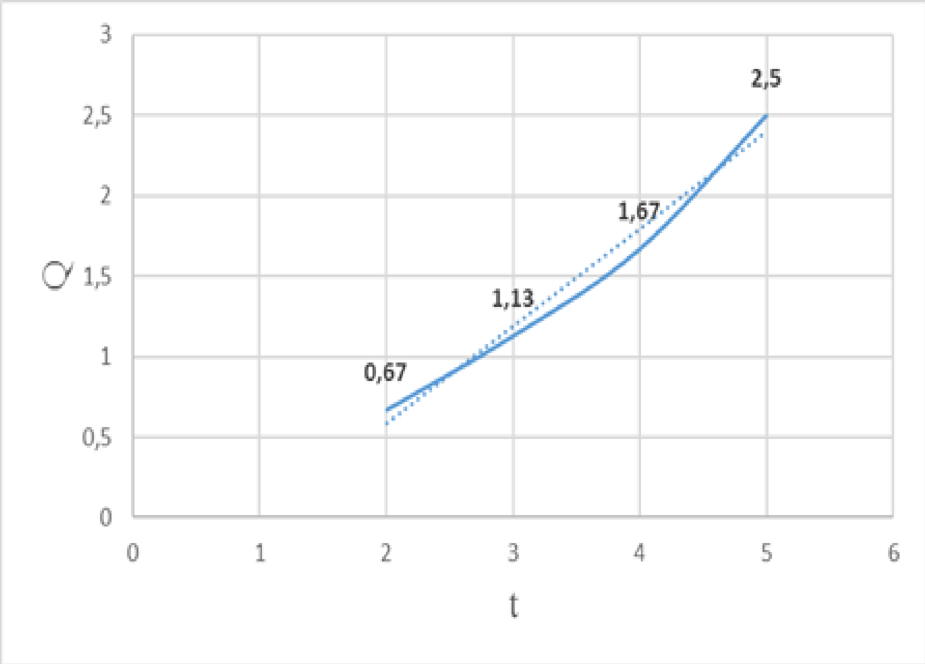


Fig 3: heat capacity of a solar water collector

A method for calculating the heat capacity of a solar water collector consisting of curved tubes has been developed. Explanatory schemes related to the Puazel`s equation, compressive strength in laminar flow conditions, and the nature of the fluid flow were studied. Determibing the heat capacity of a curved solar water collector, determining the thermal processes inside the collector pipes, the processes of water movement in a curved pipe, the theoretical analysis and calculations are described in detail.

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