Theoretical research on the use of siphoned, vacuum-operated pipelines to obtain safe and efficient electricity from the potential energy of reservoir water.

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Abstract:

The article outlines the safe and efficient technological system which is developed for the use of potential energy of reservoir water. Expressions for the theoretical determination of water transfer and its energy performance were obtained by the siphon method. Using the identified expressions, the energy indicators were determined that can be obtained in accordance with the parameters of the Chartak reservoir in Namangan region.

Keywords: *electricity, alternative energy, resource, hydroelectric power station, siphon, reservoir, dam, water level, pipe, atmospheric pressure, vacuum, stationary, vertical pipe, horizontal pipe, deflecting pipe, consumption, speed, power, efficiency.*

In current times electricity plays an important role in the lives of people and society increasing their ability to meet their various needs. The development of human civilization has always been closely linked to the amount of electricity used. Over the past 60 years, people's use of electricity for economic development has increased several times which has a negative impact on the environment.

Global warming is also directly related to the gases emitted into the atmosphere as a result of the operation of thermal power plants that use organic fuels. Over the next 70 years, several times more fossil fuels were mined than in the entire history of mankind. The demand for fossil fuels is growing rapidly. Fossil fuels such as oil, natural gas, coal and uranium currently form the basis of the global energy balance [1].

In particular, the demand for electricity in the Republic of Uzbekistan is growing year by year. Environmentally friendly energy technologies introduced in our country do not have a significant impact on meeting the demand for electricity. In our country, alternative energy resources are reflected in the hydropower potential of rivers, reservoirs and irrigation canals, solar, wind energy, biomass. Theoretically, renewable energy sources offer great opportunities for their widespread use. Particularly, these sources can provide small-scale energy production for facilities located in remote and inaccessible areas. This indicates the great potential for the construction of hydropower plants (HPPs) in the unique location of Namangan region. Large-capacity reservoirs operate in the region to supply water to irrigated crops. Based on the analysis of reservoir capacity and consumption, it can be noted that the use of energy potential of reservoir water has a positive economic effect. The research is aimed at determining the energy performance of reservoir water and obtaining electricity through a high-tech safety system.

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Table 1 below shows the seasonal indicators of water consumption from the outlet pipe of the Chartak Reservoir in Namangan region during the year.

Table1

Chartak Reservoir Water Consumption	January	February	March	April	May	June	July	August	September	October	November	December
Average amount of water consumption	4,70 $м^3/s$	4,80 $м^3/s$	4,30 $м^3/s$	4,10 $м^3/s$	4,10 $м^3/s$	4,15 $м^3/s$	5,50 $м^3/s$	3,10 $м^3/s$	3,50 $м^3/s$	2,10 $м^3/s$	2,20 $м^3/s$	4,50 $м^3/s$

The value of the outgoing water velocity was high because the drainage pipe was located below the dam. The results of experimental studies have shown that it is possible to generate $N \approx \frac{300kWh}{hour}$ electricity when the consumption value of water coming out of the Chartak Reservoir discharge pipe is average $Q = 3м^3/s$ [2].

The location of the reservoir water distribution pipes at the bottom of the dam reduces the strength of the dam. The effect of water pressure on the dam increases linearly from the water surface to the bottom [3]. There are also problems with landslides around the water outlet pipe under the dam. In order to prevent the above-mentioned losses, a technological scheme for the construction of safe small hydropower plants has been developed, which allows efficient use of the energy performance of reservoir water (Figure 1). The proposed technological system works in the following order. The pipe passing through the safe section of Dam 2 sinks to the h_b depth as shown in Scheme 3. h_b the altitude is obtained taking into account the seasonal variations of the water level. The air inside the tube 3 is sucked through the pump 6. The water is transferred to the pipe generator 4 through pipe 1. The water from the terbogenerator is transferred to the irrigation networks through the discharge pipe. After the initial movement, the water 1 maintains its range of motion and moves at a certain speed. Using this amount of effort, it will be possible to generate electricity. The importance of the proposed system is to generate electricity along with the transmission of water while maintaining the integrity of the dam.

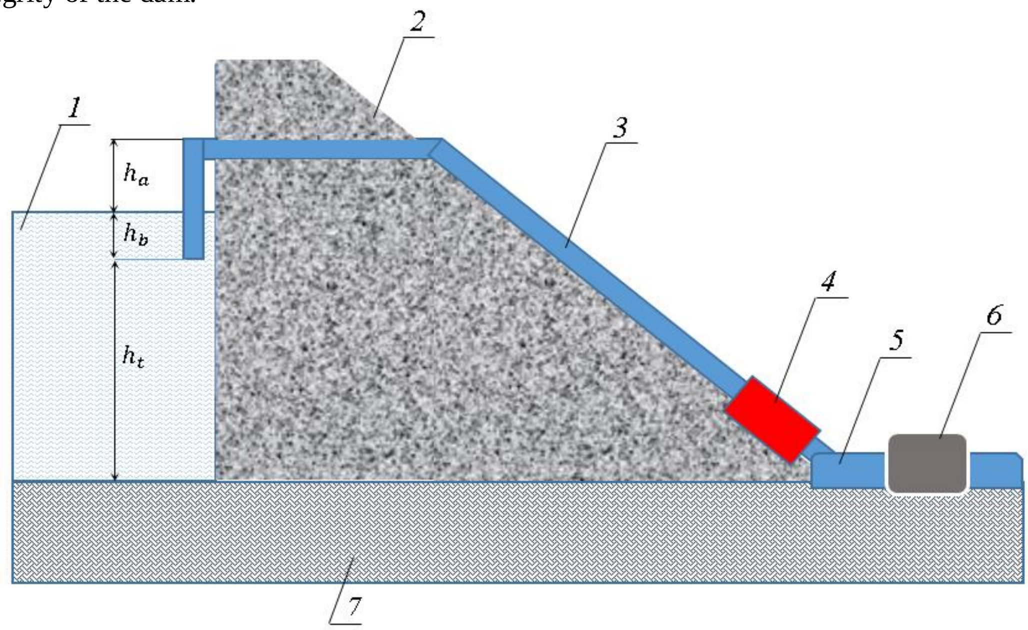

Figure 1. Technological scheme of efficient and safe siphoning of electricity from reservoir water. 1-water, 2-dam, 3-water supply pipe, 4-pipe generator; 5 discharge pipe, 6 primary suction pump, 7

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ground, h_t −height of water bottom, h_b −length of sunken part of pipe, h_a −height of pipe rising from water surface.

There are a number of advantages of obtaining electricity through the proposed technological system:
- potential energy is used along with safe water distribution;
- the integrity and strength of the dam is maintained;
- due to the purity of the water content at the water intake level, the working elements of the pipe generator are prevented;
- in case of failure of water supply pipes, additional organizational costs for repair works are received;
- Ability to safely distribute and manage the amount of water transmission. .

We will continue our theoretical research by considering the water supply pipe in the proposed system as a siphon.

A siphon is a device that connects two tanks by means of a pipe, the second tank is lower than the first in terms of level and serves to transport liquid [4]. The movement of the liquid in the siphon occurs due to the level difference of the liquids in both tanks. To start this movement, the air in the pipe is blown out beforehand. As a result, the fluid moves from the upper level reservoir to the lower level reservoir. For this reason, siphon-operated pipes are widely used in practice.

Hydraulic structures also have the ability to generate electricity using siphons. In the following, we will consider the proposed system water supply pipe as a siphon in order to efficiently and safely use the potential energy of the water in the reservoirs.

Let us consider the hydrostatic calculation of a siphon pipe for the proposed system. Figure 2 shows a water transfer scheme of a siphon pipe passing through a reservoir dam. First of all, it is important to determine the maximum elevation of water from the reservoir.

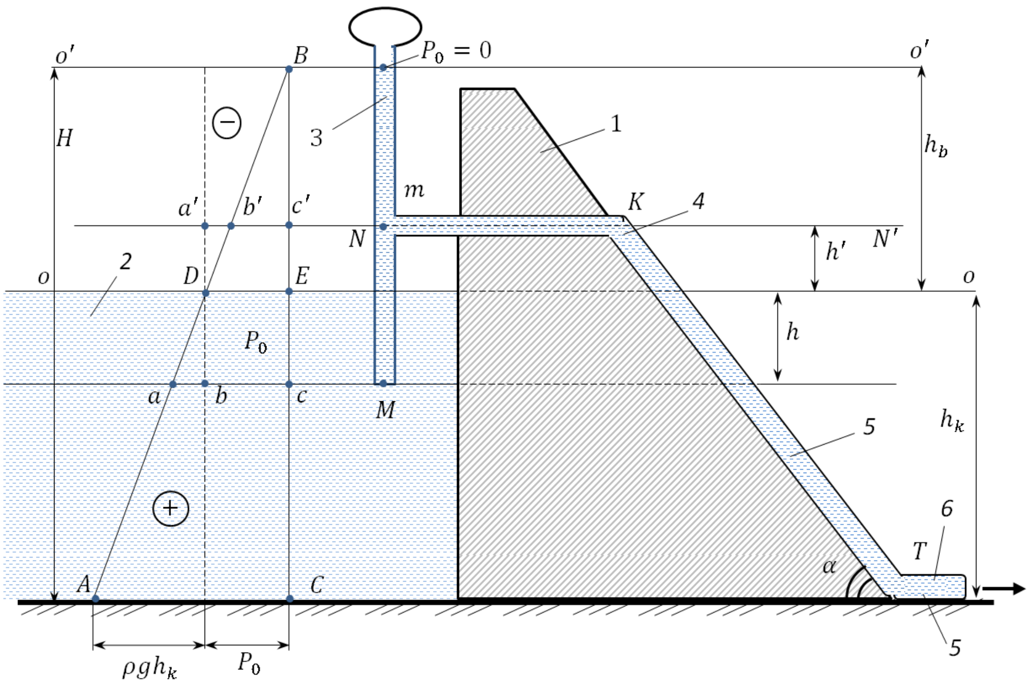

Figure 2 Water transfer calculation scheme of the siphon pipe passing through the reservoir dam. 1 dam (dam); 2-suv; 3-vertical siphon pipe; 4-horizontal siphon pipe; 5-way siphon pipe; α −the slope angle of the dam; $O-O$ free surface of water; $h_в$-vacuum elevation of water; h_k -water level; h- the height of immersion of the siphon pipe; h'- the height of the rise of the siphon pipe from the water level to the horizontal plane.

Since the upper level of the water collected in the dam is open, the external pressure force at the linear level $O-O$ is equal to atmospheric pressure, ie. along the line $O'-O'$, the value of the

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external compressive force is zero, ie $P_0 = 0$. In this case, the graph of the change in the value of the water pressure force in the vertical direction is in the form of a triangle $ABC -$ the end of the triangle ΔABC −is the total compressive force at the point $B -$, and the total compressive force $P_0 = 0$ at depth $H -$ is equal to:

$$P = P_{atm} + p\, gh_k$$

$O' - O'$ and AC −there drawn a vertical straight line intersecting at the D -point with straight lines. As a result, ΔABC −the triangle is divided into two parts. ADEC -determines the full water pressure force at the bottom of the trapezoidal line $O - O$. the triangle ΔDBE −determines the water pressure at the top of the line $O - O$. We select the water inside the siphon from the liquid at two points: M and N. M the point from the surface of the water to the end of the submerged part of the pipe and the point N corresponding to the horizontal plane of rotation of the pipe above the water level. We determine the water pressure force at these points using a triangular shape ΔABC −The compressive force corresponding to the point M is equal to the length of the cut ac:

$$ac = ab + bc \qquad (1)$$

Where bc-external pressure.
P_0=P_{atm} ab- is an additional compressive force, defined by the following expression:

$$P_q = p \cdot g \cdot h$$

where $p -$ is water density.
In this case, the total compressive strength at the point $M$is determined by the following expression:

$$P_M = P_{atm} + p \cdot g \cdot h \qquad (2)$$

We determine the compressive strength of water at the same point$N$:

$$P_N = P_{atm} - p \cdot g \cdot h' \qquad (3)$$

or, in general, the total compressive strength can be determined by the following expression:

$$\mathrm{P_{full}} = P_{atm} \pm p \cdot g \cdot h \qquad (4)$$

It can be seen from this expression (4) that the total compressive strength and atmospheric compressive strength can be a positive sign, or inequality. If so, the difference between them is called the vacuum state and $h_b -$ is called the vacuum height, which means that the water level h_b −can rise to a height inside the vacuum tube.
Using Figure 2, ΔABC −we determine h_b −the height at which the water can rise.
In terms of similarity $\Delta ABC \sim \Delta DBE$, we can write the following expression:

$$\frac{DE}{AC} = \frac{h_b}{H} \qquad (5)$$

here:

$$DE = P_0;\ AC = P_0 + P_q; H = h_k + h_b.$$

(5) The elevation of water in vacuum mode is given by:

$$h_b = \frac{DE}{AC} \cdot H \Rightarrow h_b = \frac{DE}{AC} \cdot (h_k + h_b) \Rightarrow h_b \left(1 - \frac{DE}{AC}\right) = \frac{DE}{AC} h_k$$

Out of this $h_b = \frac{\frac{DE}{AC}}{1-\frac{DE}{AC}} \cdot h_k$ (6)

From the expression (6) for determining the rise of water in a vacuum, we derive the following:

$$\frac{DE}{AC} = \frac{P_0}{P_0 + P_k} = \frac{1}{1 + \frac{P_k}{P_0}} = \frac{1}{1 + \lambda}$$

here we can write expression (6) as follows:

$$h_b = \frac{h_k}{\lambda}. \qquad (7)$$

Hence, $N$the location of the point is determined based on the fulfillment of the inequality $h' < h_b$.
We check the movement of water in the horizontal pipe described in Figure 3:

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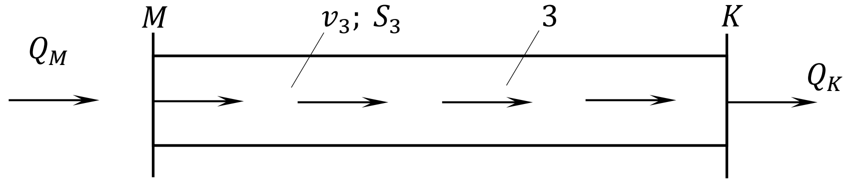

Figure 3. Calculation scheme for determining the movement of water in the horizontal part of the siphon $v_3 -$. Here, the velocity of the water in the horizontal pipe; S_3 −the cross-sectional area of the pipe, $Q_M, Q_K - M$ ва K the inflow and outflow of water in the section.

Water consumption through the pipe is determined by the following expression:

$$Q = v \cdot S \quad (8)$$

Here $M$and $K$the equation of the amount of water consumption passing through the sections is appropriate :. $Q_M = Q_K$.

We perform the calculation of the hydraulic siphon for the plot $NN' -$ as follows: $O - O$ ва NN' and write the Bernoulli equation for the water level [5]:

$$\frac{P_0}{p \cdot g} = h' + \frac{v^2}{2g} + \frac{P_{N-N'}}{p \cdot g} + h \quad (9)$$

Or $$V = \mu_c \cdot \sqrt{2g \cdot h'} \quad (10)$$

where μ_c −water consumption is determined using the following formula:

$$\mu_c = \sqrt{\frac{d}{\lambda \cdot l}} \quad \lambda = \frac{0{,}31464}{R_e{}^{0{,}25}} \quad (11)$$

where d −the diameter of the pipeline; l −pipeline length; hydraulic friction coefficient; R_e −The number of Reynalds.

Based on the above expressions, we can write the expression for determining the velocity of water in pipe 3 as follows:

$$v_3 = v = \mu \cdot \sqrt{2g \cdot h} \quad (12)$$

Since the movement of water in a horizontal pipe is stationary:

$$v_M = v_K = v = \mu \cdot \sqrt{2g \cdot h}$$

equality is appropriate.

We determine the dynamic pressure force in the cross section of the water flow $4 - 4$ described in Figure 4 (Figure 4).

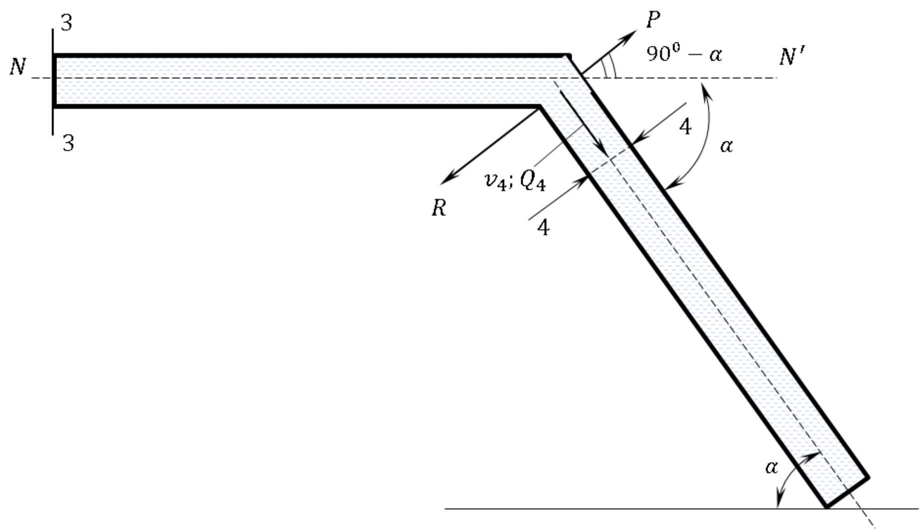

Figure 4. Scheme for determining the dynamic pressure force in the cross section $4 - 4$ (flow pipe) of water flow.

$3 - 3$ and $4 - 4$ for the cut-off interval we construct the equation of change of the amount of water movement:

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$$p \cdot (Q_4 \cdot v_4 \cdot \cos\alpha_1 - Q_3 \cdot v_3) = R \cdot \cos(90-\alpha) \quad (13)$$

$$\text{Or } p \cdot (Q_4 \cdot v_4 \cdot \cos\alpha_1 - Q_3 \cdot v_3) = R \cdot \sin\alpha \quad (14)$$

Here , $R = -P$, $R -$ reaction force, $P -$ compressive strength,

The expression for determining the compressive strength according to the expression can be written in the following order:

$$P = p \cdot Q_3 \cdot (\frac{v_3}{\sin\alpha} - v_4 \cdot cos\,\alpha) \quad (15)$$

It is known that the motion of water is stationary and the following equation $Q_4 = Q_3$ is valid. From this we can conclude that $v_4 = v$ equality follows. From expression (15) we can write the expression for determining the compressive strength as follows:

$$P = p \cdot Q_3 \cdot v(\frac{1-\cos\alpha}{\sin\alpha}) \quad (16)$$

The water consumption in the third section is as follows:

$$Q_3 = S \cdot v_3 = S \cdot v \quad (17)$$

Putting (17) ⇒ (16): $P = p \cdot S \cdot v^2 \cdot K$ (18)

Here: $K = \frac{1-\cos\alpha}{\sin\alpha}$ −coefficient. Hence the pressure force of the water in the flow pipe is determined using formula (18).

As an example, we determine the compressive strength of the deflection pipe described in Figure 4 by applying the above formulas. In accordance with the layout and capacity of the Chartak reservoir, located in Chartak district of Namagan region, we determine the energy indicators that can be obtained using the proposed system:

- angle of inclination of the bending pipe: $\alpha = 45^0$;
- compressive strength $P_0 = P_{\text{атм}} = 9.8 \cdot 10^4 \frac{\text{Н}}{\text{м}^2}$;
- submersion height of the siphon pipe: $h = 4\text{м}$;
- height of the siphon pipe from the water level to the horizontal plane: $h' = 6\text{м}$;
- water density: $p_{water} = 1000 \frac{kg}{\text{м}^3}$;
- acceleration of free fall: $g = 9.8 \frac{\text{м}}{\text{с}^2}$;
- water level: $h_k = 21(\text{м})$
- siphon pipe diameter: $d = 400\text{мм}$;
- the length of $MK$the horizontal pipe $l = 15\text{м} = 15000\text{мм}$;
- underwater pressure: $P_k = p \cdot g \cdot h_k = 20.6 \cdot 10^4 \frac{\text{Н}}{\text{м}^2}$;

We determine h_b the height of the hydrostatic vacuum. If we specify $\Delta_0 = \frac{P_k}{P_{a0}}$,

hydraulic friction $h_b = \frac{h_\text{к}}{\Delta_0} = 10$ м will be coefficient

$$\lambda = 0.11(\frac{k_e}{d} + 68/Re)\text{^}0.25;$$

In that case, the total pressure is determined by the following formula $P_t = P_0 + P_k$;

$$h' = 6\text{м};\ h_b = 10\text{м};\ h' < h_b\,.$$

the condition of inequality is fulfilled.

The velocity of water in the pipeline is determined as follows:

$$v = \mu_c \cdot \sqrt{2g \cdot h}\,(\frac{\text{м}}{\text{s}}) \quad (19)$$

Here, μ_c −the water consumption coefficient in the system is equal to the following:

$$\mu_c = \sqrt{\frac{d}{\lambda \cdot l}}$$

The pressure force applied by the water flow to the pipe generator shaft is calculated as follows: $P = \rho \cdot S \cdot v^2 \cdot K$

Here , $K = \frac{1-\cos\alpha}{\sin\alpha} = \frac{1-\frac{\sqrt{2}}{2}}{\frac{\sqrt{2}}{2}} = \frac{2}{\sqrt{2}} - 1 = 1{,}38;$ (20)

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Determining the flow of water from the pipe by the following formula:

$$Q = S \cdot v(\frac{м^3}{s}); \quad (21)$$

It is planned to build a small hydropower plant with a turbogenerator, taking into account the existing territorial capacity of the Chartak reservoir. In accordance with the expressions defined above, we determine the power rating that can be obtained through the proposed system. To do this, we use the following formula [microges]:

$$N = H \cdot Q \cdot g \cdot \eta_т \cdot \eta_г \quad (22)$$

Here, N (kWh) –power $H(м) -$ is the full hydrostatic pressure of the water, which is appropriate for the system $h = 4m$ we propose; The efficiency of the turbine $\eta_т \cdot \eta_г$ –and the generator are, in general, the following values: $\eta_т = 0{,}85$; $\eta_г = 0{,}7$ [trubogenerator FIK].

The graphs in Figures $5 - 8$ show the laws of change of basic parameters in the design of small HPPs based on the siphon system.

In determining the value of electrical energy that can be obtained, the seasonal immersion depth change of the siphon pipe must be taken into account. This value $0 \leq h \leq 10$ can vary within the limit.

Analysis of results:

The graph shown in Figure 5 shows a graph of the change in the diameter of $d = 400мм$ a siphon pipe depending on the values of the velocity of the moving water, its immersion depth h. From the graph we can see that as the depth of $h$immersion of the siphon pipe increases, the velocity of the water moving in the pipe increases on the basis of a nonlinear parabolaic law. When the siphon $v$forms $h = 10м$ the submersible depth of the pipe, it is equal to the maximum velocity of $v = 12м/s$ the water moving in the pipe.

The graph shown in Figure 6 shows a graph of the change in the diameter of $d = 400мм$ the siphon pipe depending on the different values of the moving water pressure force P, h the depth of immersion of the pipe. From the graph we can see that the increase in the immersion depth of the pipe h increases with the linear regularity of the water pressure force acting on the pipe. For example, when the depth of immersion of the pipe $h = 9м$ is reached, the pressure force of the water reaches $P = 7000$ H its maximum value.

Figure 7 shows a graph of the flow rate of water $-Q$ flowing through the pipe, depending on the depth of immersion of the siphon pipe, and $h$the depth of immersion of the pipe.

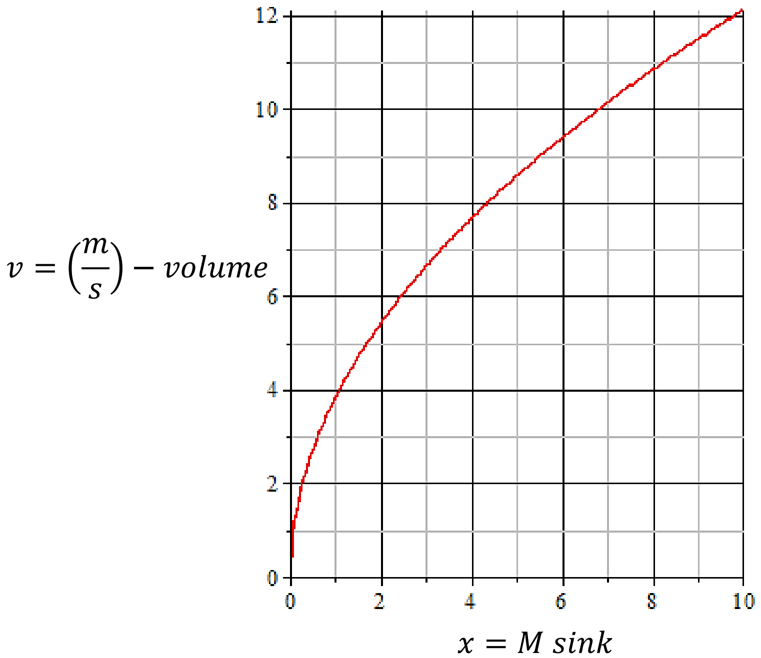

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Figure 5. The law of change of the velocity of water moving in the diameter $d = 400$мм siphon pipe, depending on the different values of the depth of $h$immersion of the pipe.

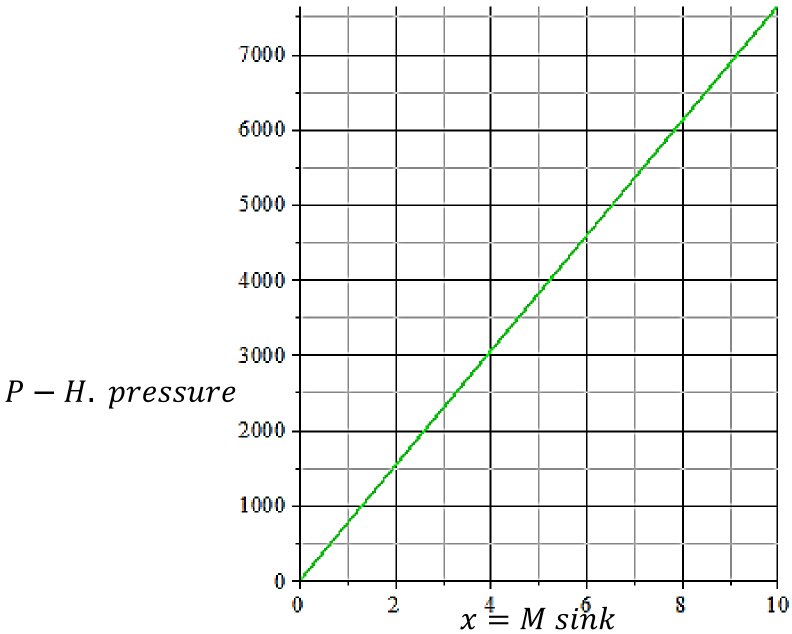

Figure 6 The law of variation of the pressure of the moving water $d = 400$мм in the diameter siphon pipe depends on $-P$ the different values of its immersion depth h.

We can see that the amount of water Qflowing through the pipe increases on a nonlinear basis with the increase of h When the depth of immersion of the pipe with the diameter $d = 400$мм is the maximum $h = 10$м, it is equal to the maximum value of

$Q = 1{,}5\frac{м^3}{s}$ the water flow through the pipe.

Figure 8 shows a graph of the change in electrical power N that can be obtained through the proposed system depending on $h$the immersion depth of the pipe. From the graph we can see that as $h$the depth of immersion of the pipe increases, the value of the electric power N obtained increases in a nonlinear pattern. When the immersion depth of the pipe reaches (22) the maximum value $h = 10$м, it is possible to obtain electricity $N = 78\ kWh$ according to expression.

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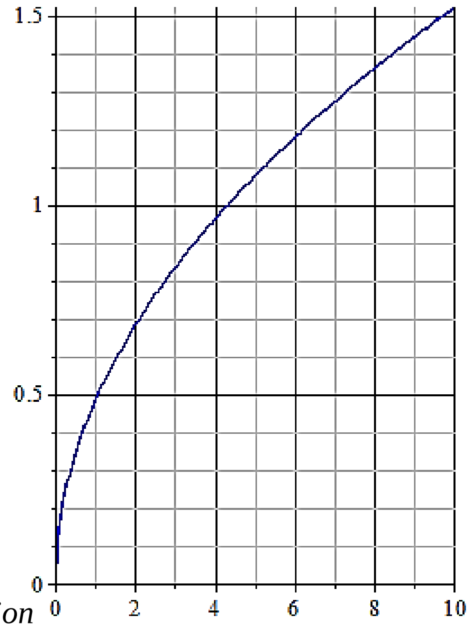

Figure 7. The law of change of the flow of water – Q moving in a siphon pipe with a diameter $d =$ 400мм depends on different values of h its immersion depth.

$x = M\ sink$

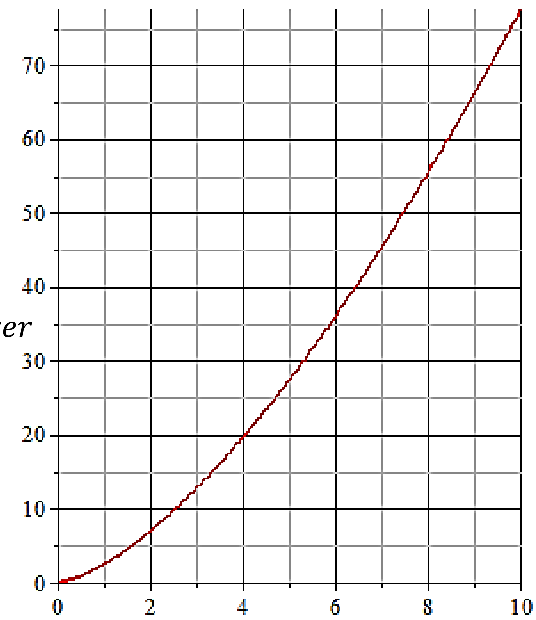

Figure 8. The electrical energy—N that can be obtained in a siphon system is a law of variation depending on $h$the immersion depth of the pipe.

Conclusion:

- A safe and efficient technological system for the use of potential energy of reservoir water has been developed, with specific advantages;
- Theoretical studies of water transfer by siphon method and its energy performance;
- The hydrostatic calculation of the siphon pipe for the proposed system is given. The vertical maximum elevation of the siphon pipe from the water level in the reservoir dam was determined.

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- The formula and graphs of the available electric power, depending on hydrostatic parameters of water are given.

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