Determination of the maximum suction height of the pumping unit (using the example of the pumping station in Dvin)

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Annotation. The Dvin pumping station is designed for subsidized supply of up to 180 liters/s from Artashat Canal to Dvin Canal for the purpose of irrigation of lands under the Dvin Canal.

The water supply from the channel to the receiving pool is carried out in a non-pressurized mode of movement through a concreted channel of rectangular cross-section of short length, the bottom of which is above the water level in the channel at a minimum depth of flow. The receiving pool communicates with the canal through a short pipe. Here the problem arises of determining the height of the maximum suction of the pumping unit. In this paper, it is solved using modern methods of mathematical measurements, which can be an exa

Keywords: channel, water movement, maximum suction height, pumping unit.

Introduction. A number of works by the author of this article are devoted to the issues of hydraulic calculations of pumping stations [1, 2, 3].

Armenia's water resources are formed mainly due to regional atmospheric precipitation and water flows of the Araks and Akhuryan border rivers. Although most researchers agree on the sources of formation of water resources in Armenia, however, various aspects are taken into account when assessing their reserves [4, pp. 45, 5, pp. 27 and 34, 6, 7, 8, pp. 84 and 278, 9, 10, pp. 63-67, 11]. According to some researchers, Armenia's water resources tend to decrease, steps are being taken to use them efficiently, and the construction of pumping stations is becoming relevant.

The Dvin pumping station is designed for subsidized supply of up to 180 liters/s from Canal of Artashat to Dvin for the purpose of irrigation of lands under the Canal of Dvin.

The outdoor pressure pool of the pumping station is located next to the right wall of the Canal of Dvin, which is connected to the canal by a rectangular opening. An outdoor swimming pool receiving a rectangular section of the pumping station, the floor mark of which is equal to the mark of the bottom of the channel, is located in the area between the engine room and the reinforced wall of the channel.

The main part

The water supply from the channel to the receiving pool is carried out in a non-pressurized mode of movement through a concreted channel of rectangular cross-section of short length, the bottom of which is above the water level in the channel at a minimum depth of flow. The receiving pool communicates with the canal through a short pipe.

Initial data

1.Static pressure	H_0 = 49-51.5 m
2. Maximum flow	Q_{max} =180 l/s
3. Minimum flow rate	Q_{min} =150 l/s
4. Design flow rate	Q_{max} =175 l/s
5.Pipeline length	L= 1476 m

Choosing the pipeline diameter

The steel pipeline of the pumping station is single-branched. The diameter of the pipe for supplying the calculated flow rate Q = 175 l/s is selected from the table of economically optimal diameters [12].

D=400 mm, or D=450 mm:

The water flow rate for the selected diameters, for the calculated flow rate will be:

V_{400}=4Q/3,14D^2=4 x 0.175/3,14 x 0.4^2=1.40 m/s.

V_{450}=4Q/3,14D^2=4 x 0.175/3,14x 0.45^2=1.10 m/s.

Since the liquid flow rate in the pumping pipeline is small, we will also discuss the issue of choosing a pipe with a diameter of d = 350 mm.

The water flow rate for a pipeline with a diameter of d =350 mm will be:

V_{350} =4 x 0.175/3.14 x 0.35^2=1.82 m/s.

Let's determine the pressure loss in the pipeline:

$$h'_W = 0.0827\frac{\lambda L}{d^5}Q^2$$

The table shows the calculation results:
L=1476, Q=175 l/s

The discharge pipeline has 10 clearly defined angles in the plan, which are the causes of pressure loss. Let's assume a local pressure loss of 7% of the longitudinal losses.

Since the maximum static pressure of the pumping station is 51.5 m, from the point of view of pressure losses, economically advantageous pipe diameters d_1 = 400 mm and d_2 = 350 mm are acceptable.

The total pressure loss in the discharge line will be:

$h_W = 1{,}07\, h'_W$:

d_1= 400 mm, $h_W =$ 8,40 m

d_2= 350 mm, $h_W =$ 17.0 m.

The required pressure H developed by the pump will be:

$H=H_0 + h_w$ (H_0=51,5 m)
d_1=400 mm, H=51,5+8,40 =59,90 m
d_2=350 mm, H=51,5+17,0 =68,5 m.

Now let's choose one of these two acceptable options from the point of view of the developing pump pressure:

The pressure developed by the pump:

D mm	λ	$0.0827\frac{\lambda L}{d^5}$	h'_W m
450	0,0209	150/138	6 /4,22
400	0,0216	256	8,5/7,85
350	0,0224	524/518	18/15,9

$H=H_0 + h_w$.

With a diameter of d_1=400 mm H=51.5+8.40=59.9 m,

With a diameter of d_2 =350 mm H=51.5+17.0=68.5 m.

Let's choose a pump according to the following pairs of parameters:

a. Q=175 l/s, H=60 m
b. Q=175 l/s, H=68 m.

From the pump catalog, option a. corresponds to the pump brand 12 D-9.

In the catalog for option b. the area is empty.

Therefore, a pumps of type 12D 9 with a diameter of the impaler D = 432 mm was selected for the pressure front of the Dvin pumping station[1].

Characteristics of the pumping unit:

The diameter of the impeller D=432 mm,

Revolutions – n = 1450 rpm,

The rated power of the electric motor is N_{electr} =170 kW,

Voltage - 400 V:

Pipeline Characteristics:

The results of calculating the coordinates of the characteristic curve of the pipeline are shown in the table.

d= 400 mm, H_0 =51.5 m, $S=L/K^2$=1470/4,85≈300 s^2/m^5 δ=6 mm.

[1] Centrifugal pumps account for 80% of all pumps and it is a known fact that most centrifugal pumps have an overcapacity of 20–30%. It has been calculated that the energy wasted by all the pumps operating at present in the EC is 46 TWh on a yearly basis [1]. Improving the efficiency and reliability of the regulation of centrifugal pumps installations of low and medium power is especially important in water supply systems with a variable component of the load, for example, in irrigation systems and in systems with a small static head. It has been established that sliding the operating point of pumps along the pressure-flow characteristic of the pipeline is the most effective method of controlling adjustable centrifugal pumps [13; 14; 15].

Q m^3/s	0,030	0,060	0,090	0,120	0,150	0,180	0,200
SQ^2 m	0,27	1,1	2,45	4,35	6,75	9,72	12
$H=H_0+SQ^2$m	51,8	52,6	53,95	55,85	58,25	61,2	63,5

Hydraulic parameters of the operating mode point of the pumping unit

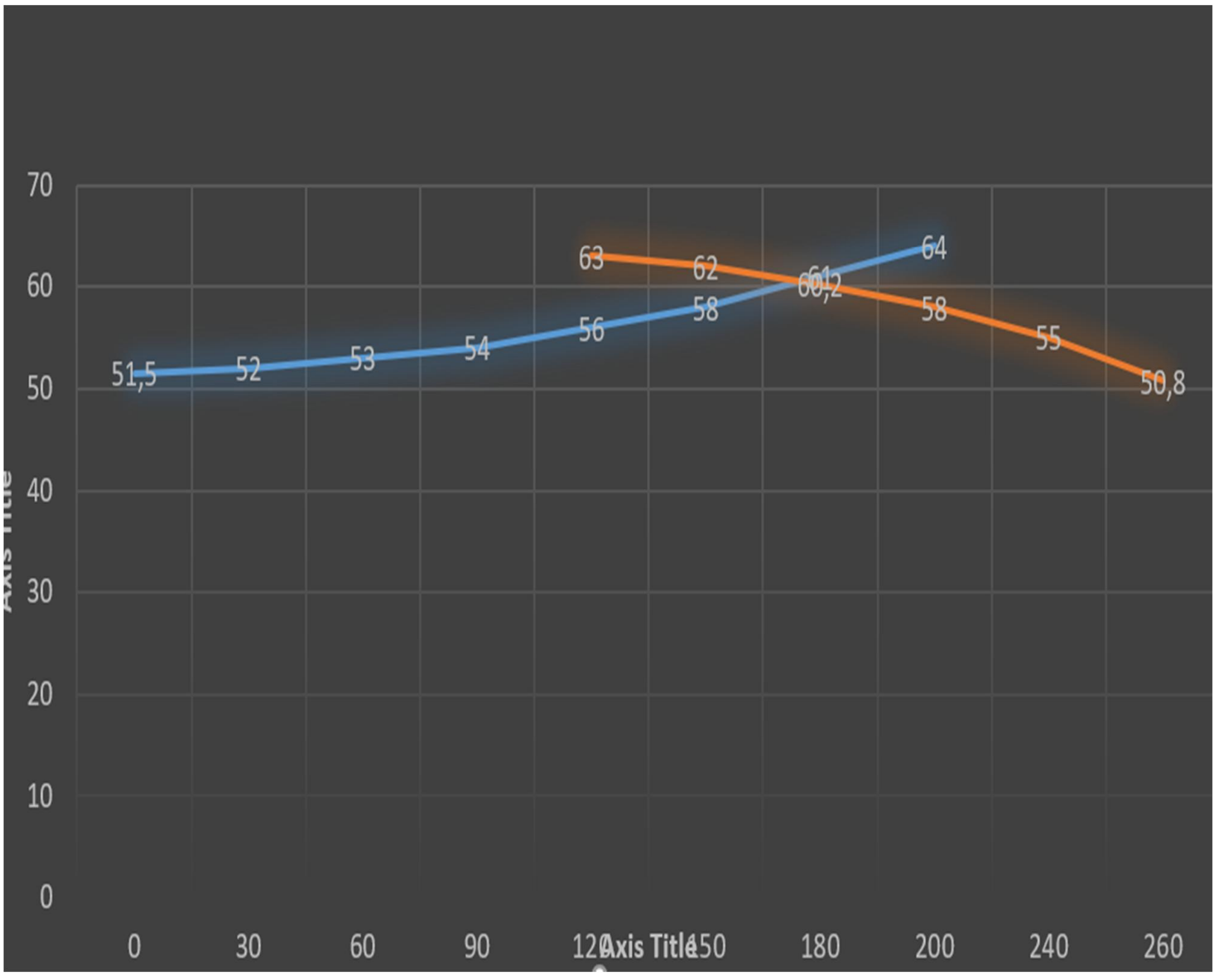

Fig. red: main characteristic of the pump 12D 9; blue: characteristic of the pipeline, the point of intersection of characteristics (Q=175 l/s; H=60 m).

The pump parameters in the operating mode (167 l/s, 61.5 m) will be:

power consumption: N_{cons} = 130 kW,

efficiency factor– 78%.

The permissible vacuum height is 6 m.

Pump Characteristics:

suction flange diameter D=300 mm,

discharge flange diameter d=250 mm,

pump weight 900 kg,

the weight of the electric motor is 1000 kg, the weight of the night together with the base plate is 3000 kg.

Determination of the maximum suction height:

At the pump installation mark (970 m) atmospheric pressure is:

P_{atm}= 9 m of water pillar.

The height of the maximum suction is determined at a maximum flow rate of

Q = 180 l/s = 0.18 m^3/s and a depth in the channel of at least h_1 = 1 m.

For a pump of the 12D9 brand, from the characteristics of the H_p^w-Q, we determined the maximum permissible vacuum value at sea level: H_p^w =6 m (*wp* – "water pressure").

The suction height of the pump will be:

$$h_s = H_p^w - h_w - \frac{v^2}{2g} = H_p^w - (\xi_{ent.} + \xi_{quant.} + 1)\frac{v^2}{2g}$$

The suction pipe has two sources of pressure loss: one at the entrance to the network and one at the 90° knee.

From the technical literature we have:

$$\varsigma_{enter.} = 5,\ \varsigma_{quant.} = 1{,}1.$$

The water flow rate in the suction pipe will be:

$$V = \frac{4Q}{\pi d^2} = \frac{4 \cdot 0{,}18}{3{,}14 \cdot 0{,}4^2} = 1{,}43 \text{ m/s.}$$

Neglecting the friction losses along the length of the suction pipe, we obtain:

$$h_S = 6 - (5 + 1{,}1 + 1)\frac{1{,}43^2}{2 \cdot 9{,}81} = 5{,}64 \text{ m.}$$

Since the atmospheric pressure at the height of 970 m of the pump installation mark is 9 meters of water jet, the maximum suction height will be:

$$H_S = h_S - 10 + H = 5{,}64 – 10 + 9 = 4{,}64 \text{ m.}$$

Conclusion:

The actual maximum suction height of the pump (at the current channel depth of 1 m) is 4.64 m, so the pump suction process is guaranteed.

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