Use of a group of underwater hydraulic tarans for the water supply system

V Y Sokolov and S A Naumov
Department of Electrical and Heat Power Engineering, Orenburg state University, Shevchenko St., 28, Orenburg, 460005, Russia
E-mail: naum090909@rambler.ru, teploosu@mail.ru

Abstract. When choosing water-lifting equipment, a number of issues related to the type of water intake structure, the energy for driving the plant, the adopted pressure and control structures, and the automation system are solved. Their structures should be simple, convenient to operate, have an affordable cost, provide the required water supply to the above areas. For agricultural water supply and irrigation of land plots located above the water source, the equipment for lifting water using the energy of the water flow - a hydraulic ram - fully meets the requirements of all known means of mechanizing the water lift. The cascade hydraulic unit operates due to dispersed energy of open water flows and hydraulic impact energy. The use of a cascade hydraulic ram plant on the river will allow the water supply of individual consumers without the cost of electricity, which is absolutely safe for the environment. The proposed topic of work is therefore very relevant.

1. Introduction
Water supply of power plant is performed using hydrotarane plant, in accordance with Figure 1.

If the pumps are replaced by a group of underwater hydraulic tarans, the need for a water intake device will run out.

A group of hydraulic tarans will need to be installed in the river channel, where the flow of water will reach the highest speed, near the farm.

If it is necessary to artificially increase the flow rate of water in the river, it is possible to locally narrow the bed by creating a fill [1, 2].

In addition, it will be necessary to build a base platform for a taran group connected by a generalizing pipeline. The base is necessary to ensure rigid fixation of each element of the underwater structure, as well as to create a single zero mark for all hydrotarans, ensuring equal initial parameters of the devices operation.

However, for all its positive qualities, the hydraulic ram also has drawbacks, which, as relatively inexpensive and convenient electricity and motorized equipment spread, ultimately led to the almost complete displacement of these motor-free pumps by conventional pumps with electric or gasoline drive. Some of these disadvantages can be compensated quite easily, but others cannot be eliminated because, as is often the case, they are a direct extension of the advantages[3-5].

Firstly, to ensure the acceleration of the flow after the next opening of the baffle valve, there should no longer be water passed there in the previous cycle. If for any reason it does not leave during the hydraulic impact, then it will prevent the acceleration of a new portion of water in the delivery pipe,
which will not gain a speed sufficient to close the baffle valve. In the best case, the flow will pick up the desired speed much longer than would have happened in the absence of water behind the baffle valve - this is the unproductive loss of water through the baffle valve and a decrease in the efficiency of the plant. Naturally, water can escape only if there is a drain, so the discharge of the delivery pipeline (more precisely, the location of the bump valve) cannot be below the level of the drain reservoir, otherwise the passed water will not be able to release the bump valve.

![Figure 1](image_url)

**Figure 1** Power plant water supply: 1 - water tower; 2 - foundation and basement; 3 - supply - discharge pipeline; 4 - ladder; 5 - gland compensators; 6 - pipe for water removal for fire extinguishing; 7 - pipe for water withdrawal for household needs; 8 - tank; 9 - tent; 10 - ladder; 11 - overflow pipe; 12 - mud pipe; 13 - discharge pipe; 14 - barrel; 15 - hydrotarane unit; 16 - ballast tank; 17 - pile

Secondly, in order to accelerate the flow in the delivery pipeline to a good speed (at least a meter per second), it is necessary to ensure an altitude difference of at least several centimeters in a section several meters long.

For these reasons, hydraulic rams cannot work in reservoirs with a constant surface level, such as ponds and lakes, as well as in flat sections of rivers, where hundreds of meters, or even kilometers of flow, there is a difference in levels in centimeter or other [6,7].

Third, a substantial portion of the water is "lost" through the discharge pipe drain. Moreover, the "lost" volume is usually many times larger than the raised volume. Of course, this water is "lost" not in vain, but does its job - its energy goes to the rise of another part of the stream. However, when the total amount of available water is low, this "wastefulness" may be unacceptable. In general, the efficiency of such pumps is determined by the correct choice of the length and volume of the delivery pipe, the ratio of the sections of the baffle and pressure valves and the forces necessary for their opening and closing, depending on the required lifting height and flow rate in the delivery pipeline, that is, in the end, the working difference in levels and water flow. Therefore, ideally, each instance of such a pump should be configured individually for specific installation conditions [8].

Fourth, when using a "classic" storage cap with air, air can gradually dissolve in the injected water, which is facilitated by increased pressure. Therefore, air must be periodically replenished. To solve
this problem, the use of a membrane hydraulic accumulator tank as such a cap, which in recent years has become an integral part of autonomous water supply systems in cottages and cottages, will help. Another way to solve this problem is that with the close location of the baffle and pressure valves and strong working hydraulic impacts with the separation of liquid from the baffle valve, it is possible to try to organize automatic pumping of air through these valves, although a number of technical problems will have to be overcome [9,10].

Finally, fifthly, the hydraulic ram has considerable dimensions. Thus, it is generally believed that the optimum length of the injection pipe is in the range of up to ten meters or more. This is due to the fact that the mass of moving and then stopping water should be large enough to provide good energy for the working hydraulic shock. Since the mass of water is directly proportional to its volume, this imposes inevitable restrictions on the minimum dimensions of more or less productive structures. And the duration of the hydraulic impact should also be sufficient so that the pressure valve has time to open and pass a noticeable volume of water, and this time is also directly proportional to the distance from the baffle valve to the supply reservoir or reservoir. However, by turning the injection pipe into a spiral, it is possible to reduce the linear dimensions of the installation several times. But the weight, determined by the necessary strength and rigidity of the structure, is unlikely to be significantly reduced [11,12].

On the other hand, the capacity of the hydraulic tank is limited by its size. Too large dimensions of the hydraulic ram will also cause problems, since all elements of the structure in the area of the working hydraulic shock must have not only sufficient strength, but also maximum rigidity. As linear dimensions grow, providing the necessary rigidity may require too thick walls and, as a result, too massive parts.

2. Materialsand Methods

Nevertheless, the classic hydraulic ram remains an extremely simple, unpretentious and very unusual device, which has been completely undeservedly almost forgotten recently.

The maximum (steady) speed can be defined as [13]:

\[
v^c = \phi \sqrt{2 g H} = \sqrt{\frac{2 g H}{l}} + \varepsilon^c;
\]

\[
\varepsilon^c = \sum \varepsilon + \mu l / d;
\]

\[
h_p = \frac{\varepsilon^c v^2}{2g};
\]

\[
h_l = \frac{\mu d v^2}{2g},
\]

Where:
- \(v_c\) is the speed of steady-state water movement;
- \(\phi\) – the resistance factor constant for the given system;
- \(\varepsilon_c\) – is the coefficient of local resistance;
- \(\varepsilon\) – coefficient of hydraulic friction;
- \(h_p\) – pressure loss on local resistances;
- \(h_l\) – head losses along the length of the feed line;
- \(l, d\) – pipeline length and diameter, respectively.
It should be noted that the operation of the hydraulic ram is carried out at an unknown water speed. Studies have established that its value is defined as:

\[ V = 0.99u_c \]  
(5)

Upon reaching the speed value and, by force from the water velocity head, the impact valve rises rapidly upwards, stopping the flow of liquid. Hydraulic shock occurs (injection stroke). The force of the velocity (dynamic) head can be determined by the formula:

\[ P_{ad} = \frac{p \cdot v^2 \cdot w \cdot t}{2} \]  
(6)

where:
- \( w \cdot t \) is the midelian section of the valve plate;
- \( p \) – water density.

Maximum pressure of hydraulic impact is determined by formula (6). The discharge period begins from the start of the shock valve closing (opening of the pressure valve) and ends with its closing. The duration of the injection period is defined by:

\[ t_n = \frac{2nt}{c} \]  
(7)

where \( n \) – is the wave run from the working chamber to the feed tank repeated \( n \) times.

3. Results
At the same time, the hydraulic ram unit is a simple and unpretentious device, so the use of such units is relevant for energy saving.

The technologies used today in agriculture are very simplified. The reason for this is both the poor financial condition of farms and the low technological equipment of production. Thus, the development of energy-saving technologies in the agro-industrial complex is relevant, and the use of energy-saving plants using renewable energy sources is a priority, especially for remote areas with poorly developed infrastructure.

The platform will be a frame of steel profile pipes of rectangular section 80х60х4 (GOST 13663 Steel profile pipes). For the platform (frame 16 m and 4 ribs of 4 m) 32 m of steel profile pipe will be needed. As the 80x60x4mm pipe size calculations have shown, the framework will require 32 m of pipe weighing 258.24 kg[13,14,15].

The frame will need to be clad with a 5 mm thick steel corrugated sheet.

To secure the platform, piles will need to be installed using a special mechanical device to clog piles into the ground called a coper. The coper can function by manual labor or use different kinds of hammers to lift the cargo. Current species of hammers include diesel and hydraulic hammers as well as vibromolots. The principle of functioning of hammers is based on conversion of mechanical energy into kinetic energy: heavy weight rises to maximum height using the force of air, steam or diesel engine, and then descends on the pile, hitting it into the ground.

Depending on the type of soil and piles, different types of copra are used. A coper with a hydraulic hammer is most effective and is good at scoring steel, reinforced concrete and wooden piles. In addition to specialized copier installations for pile scoring, universal machines - excavators are used, for which purpose they are equipped with a suspended mast. Due to the installation of the guide on a standard crane boom, the excavator performs the functions of a pile machine in a short period of time. Wooden, reinforced concrete, steel piles and tongue fences are clogged. In our case, the piles will be electric welded seamless pipes with a diameter of 273 mm and a wall thickness of 12 mm. Metal piles and tongue fences immersed with clogging are coated with anticorrosive coating.
The cost of pile works (the price of pile scoring) depends on a number of factors: the method of immersion, the depth of pile immersion, the section of pile, the category of soil, the scope of works, the complexity of the project.

Piles will need to be submerged into the ground to a depth of 1.5 m. In summer the water level in the line is 1.5 m, and in the flood in spring rises by a maximum of 0.8 m. When raising the hydrotaran assembly to the surface, the structure should be held on piles, as well as not damaged against the upper control platform, so it is necessary to provide another 1 m of pipes above the water surface. Thus, the length of each pipe will be 4.8 m. We need 2 pipes. Total length - 9.6 m. Weight of one running meter of electric welded seamless pipe 273х8 mm is 52.28 kg, then total weight - 502 kg.

The diameter of the pile hole in the platform shall be greater than twice the diameter of the pile. In our case, the diameter will be 0.45 m. This is necessary so that when the platform of the hydrotaran assembly is lifted to the surface of the water, the plastic pipeline (extending to the water tower and laid in the ground) can bend behind the platform to the surface[16,17].

The fact is that this pipe will be taken with a margin of length, which will be compensated by the inclination of the pipeline underwater. And when the platform is lifted, the gap between the hole in the platform and the pile will ensure free straightening of the pipeline. The path of the platform relative to the pile is shown in Figure 2.

![Figure 2 Platform path relative to pile in three different positions.](image-url)
All plastic pipe connections will be provided with compression fittings. They are used for small diameter pipes (110 mm or less), i.e. where flange joints, but welding joints are not economically feasible or practical, compression fittings (crimping fittings, collet crimping joint) are used. Collet crimping joints are designed for pressure up to 16 atm. In these joints resistance to mechanical loads is provided due to cutting of teeth of split plastic bushing into the pipe, and tightness - rubber sealing ring.

The main advantages of compression fittings are: easy installation; Repairs that do not require special skills and tools; Multiple assembly-disassembly (up to 10 times); Absence of metal elements in the joint and, consequently, high corrosion resistance, hygienicity and durability; Possibility of connection with elements of other materials (cranes, pipes, hoses).

Coarse filters in the form of mesh with a cell of 0.005 m to catch garbage and prevent ingress of fish and other hydrotaran into the pipeline should be installed directly on the ram in the form of a removable nozzle for periodic mechanical cleaning. Almost general (full) surface area of the mesh filter choose such that it exceeded the area of an entrance opening in the case (or pipe cross-sectional area) for 40%. In such a case, we will increase the diameter of the inlet section of the filter nozzle by 40%, and it will become 0.4 x 0.228 = 0.319 m.

So-called filters will need to be periodically maintained (cleaned), turning off one group of hydrotaran at the time, with the second group switched on. The filters must be cleaned in turn.

In order to clean the filter, as well as to carry out repairs (if absolutely necessary), each hydraulic ram must be disconnected from the system by means of a cover that will cover the inlet section of the supply pipe. At that, at disconnection the device will automatically turn off locally. At the same time, however, the pressure in the common (generalizing) pipeline will decrease by an amount (at the output of one ram) of about 21500, which is 0.215 at - this is very small and does not significantly affect the supply of water to the water tower [19,20].

Hydrotaran C 1 2465488 RU F04F 7/02 (2006.01) is offered for water supply to the thermal power plant. Underwater hydraulic ram Zagumennikova N Y, Sokolov VY, Naumov S A, Sadchikov A V, Gorichev SV, Lavrentiev A V, Korobkov A I - № 201112658/069; Zayav l. 16.06.2011. The hydraulic ram according to Figure 3 comprises a housing, a supply pipe including a hydraulic pipe with an impact valve on the rod, connected to the delivery pipe by means of a delivery valve and an air cap, and to the discharge pipes according to the invention, the supply pipe is made in the form of a confuser, according to the example of an inlet pipe. A (tapered) portion of the venturi flowmeter, the diameter of the inlet section D being four times the diameter of the section d, Which increases the flow rate of the liquid by 16 times, and the shape of the drain nozzles is conoidal; Having the highest capacity and flow rate, the speed required to operate the impact valve is achieved faster, Which increases the frequency and force of the hydraulic shock, thereby increasing the frequency of water supply to the consumer; In the housing on the hydraulic pipe at the point of maximum flow velocity there installed is a catchment ring communicating with it by means of holes uniformly located along the pipe section, the total area of which should be equal to the area of flow section of the hydraulic pipe, which reduces friction.

Fluid molecules against the walls of the hydraulic tube and provides a more complete use of the hydraulic impact energy, hence a greater supply of water to the consumer; Impact valve consists of a shut-off element made in the form of a drop on a rod and a drive mechanism, which includes two cylinders combined by a coupling, in one of which a permanent magnet of cone shape is built, and the rod contains rigidly fixed thrust and steel ring, which simplifies the valve mechanism and ensures its reliable and uninterrupted operation. Figure 3 shows an underwater hydraulic ram - general view.

The body 1 of the underwater hydraulic ram is immersed in the river so that the supply pipe 2 is at a depth from the surface of 150-200 mm free end to the water flow. Water through supply pipe 2, due to difference in diameters of its inlet D and outlet d sections, Accelerating in direction of arrow B goes to hydraulic pipe 3, With the impact valve 4 open, consisting of a drop-shaped locking element 5; Providing lower resistance to liquid flow, and drive mechanism 6, the main mass falling into drain pipes 7, Conoidal shapes for providing greater fluid flow and accelerating fluid flow; And partially
into the catchment ring 8 through the drainage holes 9. Note here that the total area of said holes should be equal to that of hydraulic tube 3.

**Figure 3.** Underwater hydraulic ram – general view: 1 – housing; 2 – supply pipe; 3 – hydraulic pipe; 4 – impact valve; 5 – shows a drop-shaped locking member; 6 – drive mechanism; 7 – drain pipes; 8 – catchment ring; 9 – water passage holes; 10 – steel ring; 11 is a permanent magnet; 12 – thrust ring; 13 – coupling; 14, 15 – cylinders; 16 – threaded connection; 17 is a passage hole; 18 – rod; 19 – nut; 20 – pressure valve; 21 – delivery pipe; 22 – air cap; 23 – delivery pipe.

In the extreme open position of the impact valve 4, the steel ring 10 is as close as possible to the constant cone-shaped magnet 11, but their full connection is prevented by the thrust ring 12 which, in this position, abuts against the wall of the coupling 13 connecting the cylinders 14 and 15 by the threaded connection 16. This connection allows the frequency of operation of the impact valve to be adjusted.

Once the flow of water has gained the required speed, the shut-off member 5 will begin to move towards the passage hole 17 (blocking water access to the drain pipes 7) and with it the rod 18 with the rings 10 and 12 fixed on it. The steel ring 10 contained in the cylinder 15 and secured by the nut 19 will begin to break off from the magnet 11 by a force counteracting the magnetic attraction force to the extreme position at which the locking member 5 will completely cover the passage hole 17 - the closed position of the impact valve 4. At this point, a hydraulic shock will occur, accompanied by an increase in the pressure in the hydraulic pipe 3 due to the continuing inertia of the water flow. At this time, the pressure valve 20 opens, and water flows through the water-passing holes 9 from the water-collecting ring 8 through the pressure pipe 21 into the air cap 22, and from there, under air pressure in the air cap 22 through the pressure pipe 23 into the pressure tank to the consumer.

After the pressure in the hydraulic pipe 3 drops, when the hydraulic shock energy is consumed, the pressure valve 20 is closed in the direction of the arrow C from the pressure in the air cap 22. The im-
pact valve 4 opens, the water starts to flow again through the drain pipes 7, quickly gaining speed in the supply pipe 2 to a value necessary for closing the passage hole 17 by the shut-off member 5 so that the cycle is repeated.

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4. Conclusion
At present, the Faculty of Electric Power Engineering at the Department of Electric and Thermal Power Engineering of "Orenburg State University" is developing design and technical documentation on the basis of the proposed patents, determining and calculating design-mode parameters of the presented structures.

The proposed developments will reduce the costs of heat and electric power generation for remote consumers, as well as save the consumer from the high costs of tracing networks both thermal and electric. The use of hydrotarane plants will eliminate electric pumps, which in turn will significantly reduce the cost of electricity and maintenance personnel.

As a result, the proposed equipment allows to solve problems of energy supply to remote consumers with minimal consumption of energy resources.

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