THE RESULTS OF RESEARCH AND DEVELOPMENT IN THE FIELD OF TECHNOLOGY WATER LIFTING UNDERGROUND WATER WITH COMPRESSED AIR

Assoc. Prof. Sarkynov E. PhD1, Assoc. Prof. Karaivanov D. PhD2, Assoc. Prof. Yakovlev A. PhD3, Zhakupova Z. MSc1, Saparov N. MSc1

1Kazakh National Agrarian University (KazNAU), Almaty, Kazakhstan
2University of Chemical Technology and Metallurgy (UCTM), Sofia, Bulgaria

Abstract: The results of the research and development of technologies lifting underground water with compressed air - the creation of sizes and pneume airtift pumping systems, testing them in public and state tests: the direction for further improvement of research and development and market research carried out on the use of development in Kazakhstan.

Keywords: compressed air, underground water sources, air water lifts

1. Introduction

The use of compressed air is widely used not only in industry, transport, but also in various areas of agriculture, including the lifting of groundwater for water supply and irrigation, in prospecting and exploration of underground water and cleaning water sources (wells and dug wells) and artificial reservoirs [1,2,3,4].

Currently, for lifting water from ground water sources (wells and dug wells in the Republic of Kazakhstan, CIS and non-CIS countries; – using the mainly four areas of research on the type of water-lifting equipment is used:
- Centrifugal (submersible) pumps (producers Kazakhstan, Russia, Germany, etc.);
- Rope and belt bucket water-lifts (Kazakhstan);
- Air pump (air-lift) installations and pneumatic equipment (produced until 1992. Kazakhstan);
- Wind-pumps (Russia, China, etc.) [1, 2].

Each destination has its advantages and disadvantages:
- The first direction – centrifugal (submersible) pumps have a high standard series on the flow rate, the pressure and diameter, allowing to cover all wells on production rate and water lifting height can be used year round, but their use is limited by salinity (up to 2 g/dm³) and content in the water of solid particles (sand) - up to 0.02% by weight;
- A second direction – Rope and belt bucket water-lifts are with simple design, can be used at a higher salinity water (up to 5 g/dm³) sand and water content of 0.5% by weight, however, their use is limited by seasonal (summer and spring autumn periods) flow rate (up to 2 dm³/s), height of the water lifting (20 ... 50 m) and the inner diameter of a water source (of 150 mm or more), moreover, they are depressurized and therefore cannot convey water raised by a certain distance from a water source;
- Third direction – the air pump (air-lift) unit and pneumatic equipment have high reliability and simplicity of design of the pump can be used year round at higher salinity water (up to 15 g/dm³), and water content of solids (up to 1% by weight), with small diameters of the water sources (116 mm or more), and the process is self-cleaning water sources and improving the quality of water by aeration lifted, but the rational use of them in terms of pasture is for cleaning water sources and improving the quality of water by "depressuring" and therefore cannot convey water raised by a certain distance from a water source;
- Fourth direction – wind water-lifts (wind-pumps), their main advantage – using the wind power for pump drive, but their use is limited of wind speed (up to 3 m/s), at a wind lull days necessary backup motor for driving the pump, a small flow rate (0.5 ... 1 dm³/s) and small height of water lift (up to 20 m), large metal, restricted their use in water sources with high solids content (more than 0.1% by weight).

Under certain conditions, each direction is the current and future, including pumping systems (air-lift and pneumo) using compressed air.

The results proposed by the authors performed A.A.Yakovlev the Kazakh Scientific Research Institute of Mechanization and Electrification of Agriculture (KazNIIMESKH), development of which is being upgraded at the Kazakh National Agrarian University (KazNAU) on the grant project "Development of a new type of vacuum (air-lift) pumping plant to lift water from underground water sources using a resource-saving technologies and contributes to the quality of water lifted" through the JSC "National Agency for Technological Development" of the Ministry of Industry and Trade of the Republic of Kazakhstan, which confirms the promise and the relevance of the received research areas – air pump installations (air-lift and pneumo).

Operation of air pump units is as follows:
- For pneumo consisting of one or two cameras with a pump suction and discharge channels, which are connected to the pumping and the air guide ducts, feeding is performed by replacing the water in the pump chamber, submerged beneath a dynamic water column of water sources, compressed air, which is supplied from the pump chamber by Water-line consumer. When single-chamber pump – filing periodic, with double chamber pump – a continuous supply. Process the compressed air supply air terminal is automatically set on the receiver directly to the compressor or pump chamber;
- For air-lift, consisting of nozzle-mixer, to the suction pipe, which is connected to the pumping and the air guide ducts, feed is the method of water-air mixture that is created in the mixing nozzle by dipping her and the pipes under the dynamic level and a continuous supply of water in it through the suction pipe and the compressed air from the air guide duct receiver compressor. The process of filing water-air mixture at the optimum specific weight – 500 N/m³ carried out continuously by pumping in water-air-reception pipeline capacity out of which, after the separation of water and air, clean water drawn off through the branch line to the consumer.

Development of design, theoretical and experimental studies of air and air-lift pump installations chamber types devoted foreign and domestic works: E.G.Harris (USA, 1917); E.M.Ivens (USA, 1920); N.Swinden (England, 1924); F.Pickert (Germany, 1931); Obering Arnola (Germany, 1966); F.V.Konradi (USSR, 1949); K.A.Senik (USSR, 1949); Ya.S.Surenynas, I.L.Logov (USSR, 1955 ... 1962); R.M.Kaplan, V.E.Andriyanov, E.B.Nesterov (USSR, 1965); Ya.N.Shefter, V.D.Alyabey (USSR, 1964...1981); V.V.Serebremnikov, V.V.Bykov, V.D.Tihovidov (USSR, 1970); A.A.Yakovlev, E.Sarkynov (Kazakhstan, 1970 ... 2013) [1, 6 to 22].

The proposed work is devoted to the research and development to create pumping systems (air-lift and pneumo) carried out by the authors in KazNIIMESKH and KazNAU (Kazakhstan).

The aim of the present work: designed to offer design and technological schemes of pumping systems to lift water from underground water sources (wells and dug wells), the results of tests designed structures and market research carried out on the use of development in Kazakhstan.

Completed the development of the Air pump installations have a scientific and technical novelty for them published theoretical
2. Developed design and technology scheme of pumping plants for lifting water from ground water sources (wells and dug wells) using compressed air

Design and technology scheme pneumochamber pumping systems. Based on the review of the work of patent research and the proposed classification pneumochamber pump units (PU), taking account of established evaluation criteria – efficiency and reliability in the technology and designs, developed six new structural and technological schemes pneumochamber possessing technical, scientific novelty and usefulness: the two circuit-chamber (CA 443205), and the dual-chamber design with float-controlled air distribution schemes and dual-chamber design with an air-operated air distribution Kolpakov (CA 709840) in three variants, the scheme of the water-air method of water lift (CA 1086235) Figure 1, the scheme pneumochamber pump unit with a remote control air distribution and return of the exhaust air in the compressor suction line (CA 1142662) Figure 2, the dual-chamber pneumatic pump scheme for dug wells to the mobile version of water lift (CA 79840 and 1142662) and the scheme moisture mass separator (a.s.982739) for all structural and technological schemes of pneumo-pumping systems for compressed air cleaning of the incident.

Construction and technological schemes of air-lift pumping systems. Based on applied research in KazNIIMESKH (NGOs "Kazselhozmehanizatsiya") was developed by a constructive and technological scheme of air-lift pump station and water lift created by grazing conditions under the name BB-50А, and together with GSKB "Ovtsemash" (Kazakhstan) was developed improved size branded domestic flights BBL-3-50 (Figure 3 and 4).

Air water lifts BB-50A and BBL-3-50 are designed to lift water from the wells of pasture conditions diameter not less than 122 mm and 100 mm and the dynamic water level no more than 50 m.

Technical characteristics of BB-50A: Flow rate – 1.25 dm³/s water lifting height – 50 m, the diameter of the well – not less than 122 mm, diameter of pipes: water-lifting – 40 mm, the air guide – 20 mm, total weight – 960 kg including pipes – 740 kg, dimensions nozzle-mixing: diameter – 85 mm, length – 1750 mm, dimensions of the land – 1410*1140*1000 mm, a source of compressed air – compressor M-155-2B, with the filing by absorption – 0.6 m³/min and speed - 800 min⁻¹, the compressor drive motor – 3ИД-4,5ДУ-М, with power of 3.31 kW or УМ3-5 with 3.68 kW.

Technical characteristics of BBL-3-50: Flow rate – 0.85 dm³/s water lifting height - up to 50 m diameter of the well – not less than 100 mm, diameter of pipes: water-lifting – 40 mm, the air guide – 20 mm, total weight – 960 kg including pipe – 740 kg, dimensions nozzle-mixing: diameter – 85 mm, length – 1750 mm, dimensions of the land – 1280*890*820 mm, a source of compressed air – compressor M-155-2B, with the filing by absorption – 0.6 m³/min and speed - 800 min⁻¹, the compressor drive motor – 3ИД-4,5ДУ-М, with power of 3.31 kW or УМЗ-5 with 3.68 kW.

In the future, structural and technological scheme of air-lift pump unit and KazNIIMESKH KazNAU Yakovlev A.A. and Sarkynov E. has been improved and is protected by two provisional patents Kazakhstan number 10811 and 20252 [18, 19], the first of
which is given in Figure 5 and 6. Improvement of structural and technological scheme of air-lift pumping unit was sent to the first provisional patents (№ 10811) to reduce the start-up of air pressure at 20...40% and improve the energy performance on a second provisional patents (№ 20252) – to reduce the material consumption is 1.5...1.7 times and reduced energy performance of 1.2...1.3.

![Fig. 5 Schematic diagram of the air-lift pump station BBIL-3-50A](image)

Air-lift pump installation BBIL-3-50A consists of the pumping unit 1-6 and compressor-power unit 7. The pump includes a mixing nozzle 1 with a spring-loaded suction valve and connected to it water-lifting sections 2 and 3 air guide pipe, lowered inside the well below the water level and tight with a flat top 4, to fittings where the inside of the well-connected water-lifting pipe on the outside – the knee a drain pipe 5 and a connector hose 6 to the inlet valve.

Compressor and the power unit 7 includes a head compressor M-155-2, the internal combustion engine УМЗ-3-50A motors or starting equipment, mounted on a frame-receiver with Moisture-oil separators, pressure gauge and safety valve.

The compressor is wedge-belt drive at the start of the internal combustion engine is used as a starting clutch tip-up clip.

Work water lift. When starting the compressor, the compressed air at the opening intake valve is continuously fed from the receiver through a connector hose 6 and the air guide tube 3 to the mixing nozzle and presses the water which enters the pumping tube 2 and, after displacing the water up to a water level in the water-lifting tube in mixing nozzle body flows through the suction pipe – water. Formed in the mixing nozzle 1 water-air mixture is continuously fed to the column of water-lifting pipe 2, goes up and the expansion of the air flows out through a drain pipe 5 in water storage tank where air is separated from the water to the atmosphere. The pressure in the tank is installed and runs in a steady process air-lift pump station.

When the compressor and power unit 7 and the closing timing of the intake valve, the compressed-air nozzle terminate smexlet1, wherein the check valve sits on the seat are retained and the spring force of the residual pressure and a water column (dynamic) water lifting column being in the tubes 2, the This prevents the flow of water in the pumping tube to the static level.

When one restarts the compressor and the power unit 7 starter does not increase the pressure and the air-lift pump installation begins and continues to work in the steady state at a constant pressure of compressed air on the principle described above.

![Fig. 6 Constructive - flow chart of an an air lift pump station BBIL-3-50A](image)

3. The results of the tests developed structures pneumochamber and airlift pumping plants

Test results pneumochamber pumping systems. Test pneumatic water pump unit with abrasive particles (sand) proved the reliability of its operation with the limiting their content to 1% by weight and up to 10%.

Experimental studies of the water-air lifting method pneumochamber water pumping plant showed that feed efficiency and clearly revealed the optimal proportion zone lifted the water-air mixture depending on the height of water rise, and $\gamma_{mix_{opt}}$ with height H decreases water lift: at $H = 30 \gamma_{mix_{opt}} (7000 ... 8000)$ N/m³ at $H = 120 - (4500 ... 5000)$ N/m³ $\gamma_{mix_{opt}}$ not dependent on the air flow to lift water.

Experienced optimal values of the proportion of water-air mixture to the test water lifting heights and theoretical dependence $\gamma_{mix} = \frac{Y}{1 + KH}$ are shown in Figure 7.

The same graph is given an experimental dependence of the optimal dose relationship pipe lifting compressed air and water per cycle $V_{air}/V_{water}$, which is equivalent to the relation of time injection of compressed air and water displacement in the pumping tube $t_{inj}/t_{dis}$ the height of the water rise, it is a linear relationship with a coefficient $K = (0.008 ... 0.01)$ m⁻¹.

Calculated values of the theoretical dependence $\gamma_{mix_{opt}} = f(H)$ have a close relationship with the experiments at the correlation coefficient 0.99.

When the water-air method of lifting water at optimal operating conditions as compared with the conventional method reduces the need for air pressure to (1.25...2.05) times when $n = (120...30)$ m keeping supply at a conventional method with $N \leq 70$ m, when $R > 100$ m to 120 m, it is increased by 16% and increases efficiency pumping installation, which method reduces the load on the items and diffuser pump and increases their longevity.

Experimental studies of the age of exhaust air to the compressor suction line held by pneumatic-pump unit with an independent double-flow air terminal for remote control (see Figure 2), the results of which are shown in Figure 8 in the height range (10 ... 30) m for the mine and (31 ... 100) m for well types.

![Fig. 7 Experimental studies of the age of exhaust air to the compressor suction line held by pneumatic-pump unit with an independent double-flow air terminal for remote control](image)
Efficiency returning exhaust air into the compressor is increased by feeding (16.7...25%) and efficiency (1...4%) at H = (10...100) m with an optimum at H = 30 m, where the supply for the mine and the well types are respectively 1.57 dm³/s vs. 1.2 dm³/s (30.8%) and 1.59 dm³/s vs. 1.13 dm³/s, and from 10.2% to 14.4%.

Based key parameters for the return of spent air compressor: the optimal pressure in the return air compressor – (120...250) kPa capacity air cap Dual-Stream diffuser – (0.8...1.2) dm³. Experimentally investigated two options to the mobile dual-chamber pump water lift. The new version of the dual-chamber pneumochamber pump installation with remote air terminal: – 0.45 (0.66) kg/m³, annual economic benefit – 732.7 (968.3) USD

The results of the state tests pneumochamber pump installation with remote air terminal: – 0.45 (0.66) kg/m³, annual economic benefit – 732.7 (968.3) USD

Table 1

<table>
<thead>
<tr>
<th>The name and value of indicators</th>
<th>The height of water rise</th>
<th>Immersion depth of the pump, m</th>
<th>Supply</th>
<th>Power, kW</th>
<th>Excessive air pressure, kPa</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>100</td>
<td>2.09</td>
<td>7.5</td>
<td>3.79</td>
<td>0.41</td>
<td>770</td>
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<td></td>
<td>30</td>
<td>1.60</td>
<td>5.7</td>
<td>3.67</td>
<td>0.47</td>
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<tr>
<td></td>
<td>50</td>
<td>1.00</td>
<td>3.6</td>
<td>3.42</td>
<td>0.49</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>0.50</td>
<td>1.8</td>
<td>3.26</td>
<td>0.34</td>
<td>310</td>
</tr>
</tbody>
</table>

From these tests, it follows that all of the pumping unit with changes 20 to 70 m water lifting height up modified to decrease with increasing height of the water rise at a constant depth of immersion pump parts (nozzle-mixer) equal to 100 m, and were as follows: power – 3.79...3.36 kW; excessive air pressure – 770...310 kPa; efficiency of the pump system – 0.35...0.80, total efficiency 0.10...0.14, maximum value for water lifting height – 50 m, which corresponded to the terms of reference.

The results of the departmental test air-lift pump station BBJ-3-50A are presented Table 1.
pressure was reduced from 635 kPa to 255 kPa and Power Required decreased from 4.19 kW to 3.41 kW, efficiency was reduced and optimum – 0.157 ... 0.158 at H = 40 ... 50 m, the minimum the efficiency \( \eta_p = 0.097 \) for H = 70 m.

Fig. 9 Results of departmental tests air-lift pump station BBJI-3-50A (depending on Q, \( P_{cp} \), \( N_b \) and \( \eta_p \) = f (H).

H - the height of water rise; Q – flow rate of the pumping unit; \( P_{cp} \) - working pressure of compressed air in the system; N - power consumption, \( \eta_p \) – efficiency of the pumping unit.

Obtained at the departmental trial main BBJI-3-50A compliant specification: at the height of water rise H = 50 m, the following parameters: flow Q = 4.43 m³/h, \( P_{cp} = 450 \) kPa, \( N_b = 3.8 \) kW and \( \eta_p = 0.158 \), according to specification: Q = 2.88 ... 3.6 m³/h, \( P_{cp} = 550 \) kPa, \( N_b = 5.5 \) kW and \( \eta_p \) - not less than 0.12 ... 0.15. Tests have shown high reliability at operating time – 1074 hour and a safety factor – 1.0.

Compared to the basic pump installation improved pump assembly BBJI-3-50A has a higher pitch of 1.3 times less need for compressed air pressure of 1.14 times and higher the efficiency factor of 1.2, resulting in annual effect per unit amounted to 200 USD. Based on the positive results of the departmental test improved pump installation BBJI-3-50 is recommended for setting the base for the production of the pumping unit.

4. Findings market research carried out on the use of development in Kazakhstan

To lift water from underground water sources – wells and dug wells in the pasture, and the general public water supply on the market has the following types of water-lifting technology tools: electric submersible pumps electric submersible water lift (for grazing and general water supply and irrigation, sellers - Germany, Poland, Czech Republic, Russia, Lithuania, Moldova, Kyrgyzstan, Kazakhstan, etc.); rope water lift ВШП-50A and belt water lift BBМ-100 (for grazing conditions, the seller – Kazakhstan, the plant "Mankentzhimash"); wind-pump NGO "Vetroen" (for pasture and household conditions, the seller – Russia); small pumps of the "Малыш", etc. (for the living conditions of the seller – Russia, China).

Electric submersible pumps ECV sold through brokerage firms Kazakhstan (LLP "Kclet", etc.), water lift ВШП-50A, BJМ-100 and wind-pumps – in factories-manufacturers, domestic pumps in specialized shops.

Consumers such as farmers and farms are equally preferred to buy the belt or rope water lifts, depending on what kind of water source they have, and buy submersible pumps for water lifting height altitude (over 50 m) and where there is provision for a centralized power supply. Consumers for the total water supply (farm, settlement, etc.) and land reclamation system preference in the acquisition of submersible electric pumps.

Product market can be refilled promising pumping and technical facilities developed in KazNIIMESKH and KazNAU to lift water from wells and dug wells air pump installations: pneumatic chamber ВПКШ-5-70 for lift water from the wells of the nominal size 5 inch and more height water rise up to 70 meters and ВПКШ-30 for water lifting their dug wells water lifting height of up to 30 m; air-lift BBМ-3-50A (Figure 12) to lift water from the wells of the nominal size of 5 inches or more in height and water lift up to 50 ... 70 m.

Production base of the proposed development will significantly supplement market and thereby increase the efficiency of irrigation of pastures and agricultural water supply in agriculture of Kazakhstan. The proposed pumping stations passed the state tests and are recommended for production.

The current indicative prices of water-lifting equipment in the domestic market can be:

a) Submersible type electric submersible water lift:
   1) without water lifting pipes, cables and remote control – 1250 ... 2000 USD;
   2) with water-lifting pipe – 2300 ... 3700 USD;

b) The pump unit complete with independent power station – 2000 ... 3000 USD;

c) Pump systems pneumo:
   - ВПКШ-5-70 – 1000 ... 1500 USD;
   - ВПКШ-30 – 700...1000 USD;

d) air-lift pump units
   - BBМ-3-50A – 1000...1500 USD;

Types of markets recommended pumping systems – internal to the country with the establishment of regional networks and points of implementation, in the long term with access to international markets in the CIS countries and abroad.
of the study area and the entire region of the country. The demand of the external market – contracts with foreign firms on the basis of wide publicity of the proposed pumping systems, networking and demonstration exhibition samples.

The basis of the predicted national market adopted science-based need for pumping and technical means, depending on the amount of the consumer republic of water sources, their static distribution on the basic parameters (flow rate, dynamic level, height of the water column, internal diameter, water salinity and its content of abrasive particles) and the likelihood of each type of water-lifting technology tools of their main parameters (flow rate, water lifting height, the diametrical dimension of the pump, permissible limits for exploitation by salinity and content of abrasive particles in the water and season of use). According to scientific analysis of the scope of application of the proposed pumping units in the domestic market can be: on ВИКС-5-70 – 7000 units, ВИКИИИ -30 – 15000 units and BB/I-3-50А – 1300 units.

Competition in the markets. The area of the production of water-lifting hardware – a long-established and not subject to rapid change, it is constantly in demand, particularly promising types: belt, rope, air-lift and pneumo-pumping stations, submersible pumps, including with stand-alone power stations. The results of the market research carried out by the development showed that the proposed pumping stations to lift water from underground water sources in Kazakhstan competitive on the domestic and foreign markets, and may find application in the Republic of Kazakhstan and abroad.

5. Conclusions

Based on applied research carried out an analysis of the strengths and weaknesses of research directions for the type of water-lifting equipment used and proven relevance and prospects of the use of the water system to lift water from underground water sources and air-lift pump installations pneumatic chamber using to process compressed air.

The basic constructive – technological schemes pneumatic chamber and airlift pumping plants, which led to the pilot studies and the development of prototypes of state and departmental trials with positive results and recommendations for production, production air-lift pump station BB/I-3-50, and the introduction of farms in a pasture water supply in the whole region of Kazakhstan.

The results of the market research carried out by the development showed that the proposed installation of air-lift pump and pneumatic to lift water from underground water sources in Kazakhstan are competitive in domestic and foreign markets, and may find application in the Republic of Kazakhstan and abroad.

6. References