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OVERVIEW OF TECHNOLOGIES FOR CONSTRUCTING THE FACILITIES AT THE DNIESTER PUMPED STORAGE POWER STATION

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ABSTRACT

Purpose. Perform an overview of the construction technologies and substantiate the effectiveness of the Ukrainian experience in building a pumped storage power station (PSPS) on the Dniester River in difficult engineering-geological conditions with the construction of large underground structures, including mine shafts and hydraulic engineering tunnels.

Methods. In the work, the main technological methods have been studied and analysed of hydraulic engineering construction of complex large underground structures in the rocks with medium hardness according to M.M. Protodiakonov scale using a special method of a well lowering and a combined method of drilling and blasting operations during mine workings drivage, which is based on the slow and short-delay blasting. The anchors calculation, when driving the water sup-ply conduits, has been made from the condition of suspending the block of disturbed rock, the thickness of which was taken equal to the roof arch height according to M.M. Protodiakonov. The parameters of the sprayed plaster base concrete have also been calculated according to V.M. Mostkov theory.

Findings. The analysis of the current state of research, theoretical positions and world practice of construction of PSPS has been made, which testifies the high potential of this type of energy facilities. The efficiency of the underground hydraulic engineering construction of the Dniester Station has been substantiated. The results are presented of a complex application of mining and construction methods, as well as processing equipment for the construction of horizontal and tailrace conduits, drainage adits and vertical mines for hydraulic units in difficult engineering and geological conditions. As a result of performed analytical studies, the combined method of constructing the anchor support of sprayed plaster base concrete, when driving the water supply conduits, which is the most rational for engineering and geological conditions of increased complexity, has been substantiated.

Originality. The efficiency of the lowering well method in a thixotropic jacket when constructing in the soft soils has been deter-mined under the conditions of building a PSPS on the Dniester River. The step-by-step combined method of constructing the anchor support of sprayed plaster base concrete, when driving the water supply conduits has been substantiated.

Practical implications. The most rational ways of conducting a range of mining-construction works have been substantiated and implemented, allowing to construct a complex pumped storage facility with a capacity of over 2.0 million kilowatts, ensuring a significant increase in the power supply capacity of the West Ukraine region.

Keywords: *pumped storage power station, drainage adit, approach adit, mines for hydraulic units, water intake*

1. INTRODUCTION

In modern conditions, the use of energy sources at hydroelectric power stations of various types is of great importance for creating competitive systems for burning coal, fuel oil and gas in order to obtain cheap and efficient electric power from the energy of the sun, wind, river water and the global ocean water. The research of this kind is carried out throughout the world (Pivnyak, Beshta, & Balakhontsev, 2010; Bondarenko, Tabachenko, & Wachowicz, 2010; Medunić, Mondol, Rađenović, & Nazir, 2018; Sai, Malanchuk, Petlovanyi, Saik, & Lozynskyi, 2019).

The Greek scientists D.S. Anagnostopulos and D.E. Papantonis have performed a numerical study of the optimum size and design of a unit at the pump-filling hybrid wind-hydroelectric power station (Anagnostopoulos & Papantonis, 2007). The research results have shown that using a pump with variable velocity is an effective solution for hydroelectric power stations with less diffused potential of wind energy.

The same authors have shown in the work (Anagnostopoulos & Papantonis, 2008), that the hybrid wind energy and hydroelectric power seems to be an effective solution for isolated systems of autonomous electrical power networks. In this work, a numerical methodology is presented for the optimal various components calibration of the reversed electrical-hydraulic system, which is used for practical purposes at a number of wind-hydropower stations set on the island of Crete. As a result of applying a numerical solution for analysis of the most important parameters influence on the station operation, it was concluded that an optimized design of this type of stations is decisive for the economic viability of the studied system.

As indicated in the work of Japanese scientists (Kuwabara, Shibuya, Furuta, Kita, & Mitsuhashi, 1996), who performed the certain measurements of the design and dynamic system characteristics of the controlled pumped storage power station (PSPS) in Okavachi with capacity of 400 MW, that it can change capacity with an increment not less than 32 MW in generating mode and not less than 80 MW in pumping mode during 0.2 s. They proposed principal design solutions for station control systems and presented the actual characteristics of the plant based on oscillographic measurements and constructed diagrams.

It is shown in the work of Chinese scientists (Ma, Yang, Lu, & Peng, 2015), who develop the autonomous systems of renewable energy sources, that they are the most promising solution for electrification of remote areas without access to electrical power systems. In the present study, a system of PSPS for autonomous power supply in remote areas is proposed. Mathematical models have been developed, in which the reliability and the economic criterion of the system are substantiated as the basis for optimization. This study justifies the fact that the proposed models and an optimization algorithm are efficient and can be used for other similar variants of energy supply in the future.

The work (Deane, Ó Gallachóir, & McKeogh, 2010), which is presented in the Journal on Renewable and Sustainable Energy Systems, evidences that there is currently a technical and commercial interest in PSPS due to the emergence of systems with a higher level of generated and renewable energy. It is shown that over the next eight years after 2015, more than 7 GW of PSPS capacity will be added to the European power grid, and the similar projects are planned in the USA and Japan. The paper provides an overview of the locations and terms of new PSPS development and a detailed analysis of the trends of this technology development. This information confirms the importance of constructing the PSPSs with a return pumping, rather than a clean direct water draining, as at the existing hydroelectric power stations.

In the work of Chinese scientists (Si-hong, Gong-yuan, Jian-zhou, & Guang-yin, 2004), there is a technical overview of hydroelectric projects development. Their development, including building of giant hydro- and electricity-generating plants and PSPS is substantiated in the paper. Many projects of this type in China have withstood large floods and earthquakes. At the same time, the total specified hydropower capacity of all stations in 2014 exceeded 300 GW, and the capacity of PSPS reached 22110 MW, which is 12% of the capacity of such stations throughout the world. Thus, the level of scientific substantiation, designing and construction of PSPS in China provides the solution to the problems of floods protection, energy supply and irrigation of agricultural lands (Jia, 2016).

The studies with the use of a numerical simulation model of water filtration in a fractured rock massif are of great scientific importance (Sotskov, & Saleev, 2013; Chui, Moshynskyi, Martyniuk, & Stepanchenko, 2018; Bomba et al., 2018; Kuzlo, Moshynskyi, Martyniuk, 2018).

When constructing the upper reservoir of the Pushine PSPS in China the hydraulic conductivity of the fractured rocks in the area of construction and the overall rate of water leakage through the fractures have been determined (Li, Lu, Long, Yang, & Li, 2008). In order to reduce the level of hydraulic permeability of rocks in the dam foundation, it is necessary to strengthen it by cementation of the lower part.

As it follows from the reduced state of main provisions for the construction of PSPSs, the construction of the Dniester Pumped Storage Power Station (Dniester PSPS) is the most important factor in the participation of Ukraine in ensuring the state energy independence at the global level. The station is a complex object, the construction of which required the solution of a number of scientific problems, the substantiation of effective technologies, the appropriate level of technical equipment and the work organization.

2. CHARACTERISTICS OF THE HYDRAULIC ENGINEERING COMPLEX AND PRINCIPLE OF ITS OPERATION

Currently, the solution of the power supply problem of cities and large industrial facilities in Ukraine is performed by the way of reconstructing and constructing new hydraulic engineering structures, which include the Dniester PSPS, one of the largest in Europe. Its capacity in the generating mode is 2275 MW, and in the pumping mode – 2912 MW.

The main advantage of such a power facility is its operational ability to produce increased quantity of electricity during peak hours. This is conditioned by the operation of hydraulic units from water falling from the upper basin with 38.8 million m^3 of pondage to the lower buffer reservoir with 70.1 m^3 of pondage with the difference in elevation of the upper basin (full reservoir level is equal to 229.5 m) relative to the lower basin (full reservoir level – 77.1 m) which is equal to 152.4 m. Such design parameters during operation of seven hydraulic units with a capacity of 324 MW each for 4 hours per day will allow to achieve 2720 million kWh of annual electric power generation.

The Dniester PSPS is located on the Dniester River in the Chernivtsi region of Ukraine near the border with Moldova, about 450 km from the city of Kyiv. The chain of hydroelectric power stations is built on the Dniester River, consisting of two hydroelectric power stations and one PSPS, which is under construction. In December 2009, the first hydraulic unit of the Dniester PSPS was put into industrial commission, the second hydraulic unit – in December 2014, and the third one – in August 2016. Since then, the Tunnel Construction Department No.7 (TCD-7) of PJSC "Kyivmetrobud" has been actively involved in the construction of the Dniester PSPS as a subcontractor.

During this period, the following works have been performed. There have been driven the lower drainage adit with a diameter of 5.65 m and a length of 2604 m, an upper drainage adit with a diameter of 2.5 m and a length of 1484 m, four vertical water supply conduits with a primary lining with a diameter from 9.3 to 8.5 m and a length of 746 m and with a finishing metal lining up to a diameter of 7.5 m and a length of 530 m. In addition, three horizontal water supply conduits with an external primary finishing reinforced concrete lining with a diameter from 8.5 to 7.5 m, a length of 1084 m, and a metal lining with a length of 851 m have also been driven. Also, tailrace conduits out of three hydraulic units have been driven. At present, three hydraulic units are constructed and operating, and the fourth is under construction.

The construction project of an object at this level includes the creation of an upper reservoir, a water intake on the upper level, inlet pressure water conduits, and a facility of a pumped-storage station hence: mines for hydraulic units, drainage galleries, mines of emergency exits, tailrace conduits, water outlet and the lower reservoir with a complex of protective structures (Fig. 1).

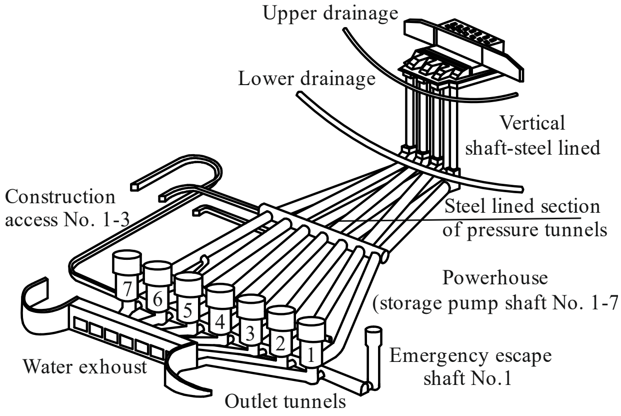

Figure 1. General view of the Dniester PSPS under construction

The operating principle of the complex under construction is as follows. Water from the upper reservoir through one of the water intakes is fed by the inlet pressure water conduit to the hydraulic unit, from where it is fed to the lower buffer reservoir through an inclined tailrace conduit (Fig. 2).

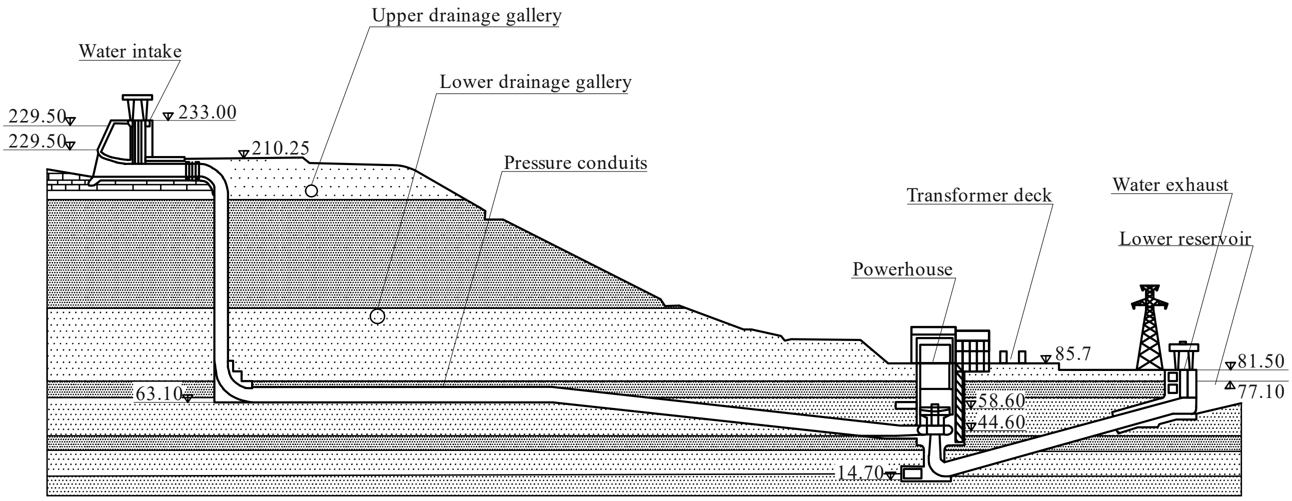

Figure 2. Longitudinal cross section of water-conveyance system at PSPS

All vertical mine workings for hydraulic units with a depth of 45.65 m are driven using a combined technology, which includes the method of well lowering and the mining method.

A lowered well is constructed on the surface by concreting with pours of 2.0 m each using special timbering and a crawler crane of the DEK-50 type with a bucket of 3.2 m^3 capacity. For its strict fixing, in the lower part around the well, from the outside, a reinforced concrete supporting ring with a height of 0.75 m and a width of 2.0 m is buried into the ground (Fig. 3).

In a well with a diameter of 32.6 m, a height of 19.0 m, and with a reinforced concrete wall thickness of 1.0 m, on the surface when removing it from a temporary base, the two DT-53 bulldozers work. The well is lowered under its own weight from the surface in a thixotropic jacket with mining the soft soils by a construction excavator of E-5015A type, equipped with a trenching shovel with a bucket of 0.75 m^3 capacity, over the entire well area, and a bulldozer of the D-492A type, which leaves the bearing zone of the well under its blade.

Outside the well and supporting ring, along circumference with a radius of 25.0 m, a crawler crane of the DEK-50 type with an elevating capacity of 50 tons is moving on the surface. It performs a soil excavation from the well, which is loaded by an excavator into the bucket with a total weight of 12 tons. The bulldozer performs layer-by-layer cutting of the soil with a thickness of 250 – 300 mm.

3. COMBINED METHOD OF CONDUCTING DRILLING AND BLASTING OPERATIONS

Further construction of the lower part of the mine shaft in the hard rocks, including oolite limestone, marl, siltstone, argillite and sandstones with various inclusions of clays, such as semi-solid, solid and hard clays, is carried out using drilling and blasting operations. In such a case, the section of the well is divided into three sectors, and the churn-drill blasting of rocks is carried out in three separate steps. In each sector, about 90 wells with a diameter of 110 mm and a depth of 2.5 m are drilled on by the NKR-100 machine.

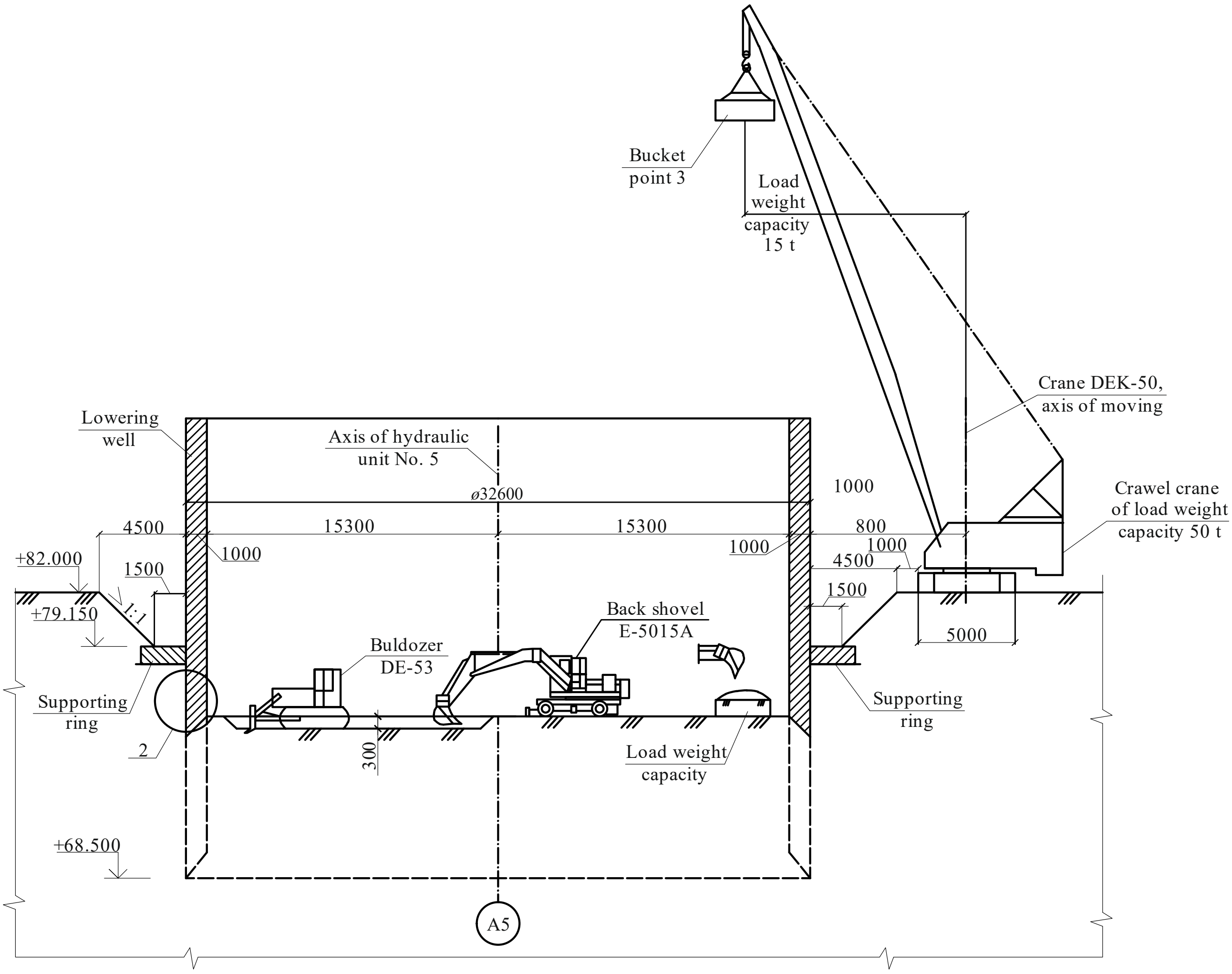

Figure 3. Flow chart of the well lowering

The wells are charged with Ammonite No.6 ZhV and are blasted in a short-delay blasting with the help of a non-electric "Impulse" type system. After the explosion, the pass value is 2.0 m with a blast-hole efficiency ratio of 0.85.

With insufficient crushing of separate rock pieces in the face after an explosion, their destruction for transportability is performed with the use of hydraulic hammer set on a face shovel.

At present, reinforced concrete horizontal and steel-reinforced concrete inclined tunnels are being driven for the seventh hydraulic unit in the area of the water outlet. At the same time, an exit track from the industrial site and a vertical mine protected from a water outlet were constructed (Fig. 4).

At the same time, an exit track from the industrial site and a vertical mine protected from a water outlet by two water blocks were constructed. A rock-loading machine of LK-1 type, a bunker and, just above, a winch of LPEP-10 type, were installed under the mine. At the industrial site, a DEK-50 crane and a bulldozer were installed for lifting and shipping the rock when driving an inclined tailrace conduit. A concrete-delivery pipeline with a diameter of 150 mm was installed along the mine and the lower part of the water conduit, through which concrete of BN-1 type is pumped for the construction of a permanent lining. This method of driving the tailrace conduits allows to mechanize fully all the major tunnelling and construction works.

Driving the inlet pressure water conduits to the mines of hydraulic units and tailrace conduits to the water outlet is carried out in hard rocks with separation into upper and lower steps (Figs. 5, 6).

Their cross section area ranges from 40 to 50 m^2, depending on the mine working type. From 100 to 114 blast-holes with a diameter of 43 mm and a depth of 3.0 m are placed on this area. The blast-holes are drilled with perforating machines with push-feed of PP-50 type or PP-60 type. These perforating machines are also used for drilling the blast-holes for the anchors. The blast-holes are divided into 5 – 6 groups according to their purpose: cut blast-holes, outer blast-holes (2 – 3 groups), contour blast-holes and bottom blast-holes. The blast-holes are charged with Ammonite No.6 ZhV. The mass of charging the cut blast-holes is 1.4 kg, in the outer blast-holes – 1.0 kg, in the contour blast-holes and bottom blast-holes is 0.8 kg. The length of tamping in the cut blast-holes is 1.0 m, in the outer blast-holes – 1.2 m, in the contour blast-holes and bottom blast-holes – 1.4 m.

Blasting of cut blast-holes and outer blast-holes charges is made by short-delay blasting at slowdown intervals of 20, 125, 250 and 450 ms. Some of the outer blast-holes are blasted with the increased cross sections.

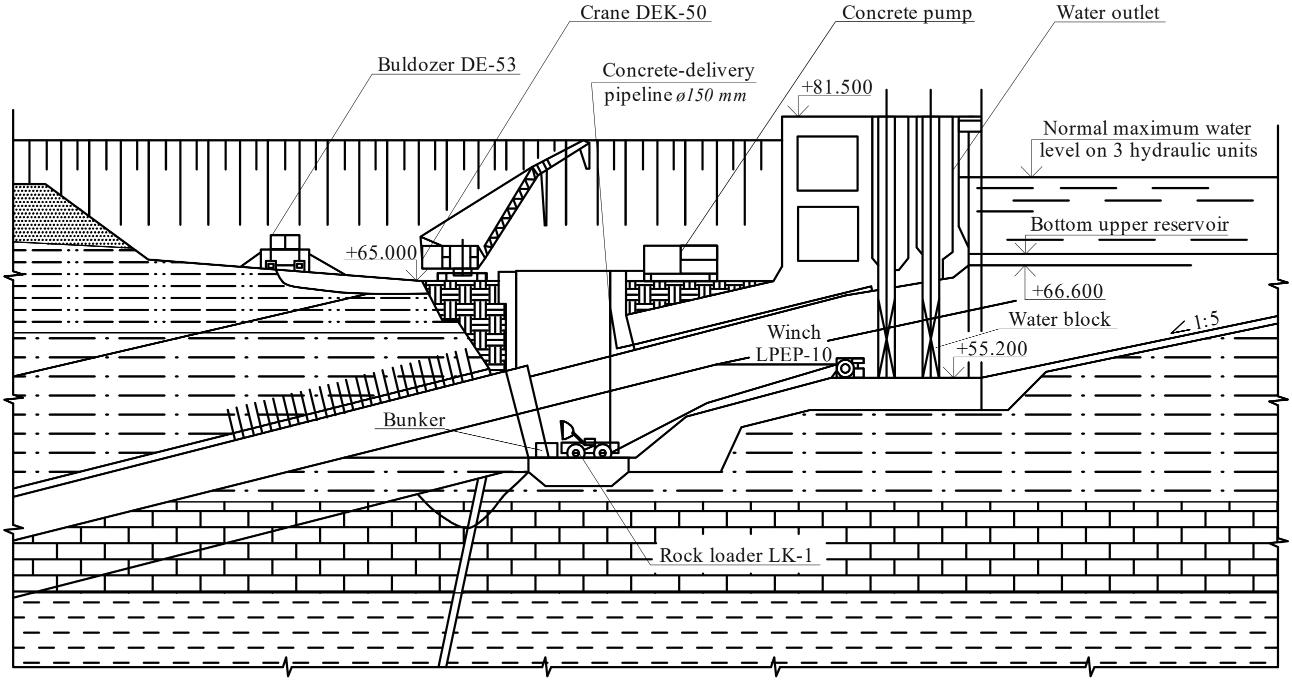

Figure 4. Scheme of mine workings and setting the equipment for driving the tailrace tunnel

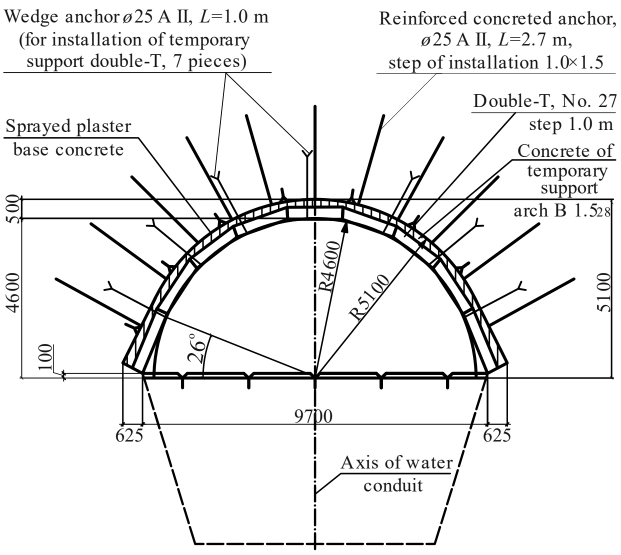

Figure 5. Cross section of the upper step

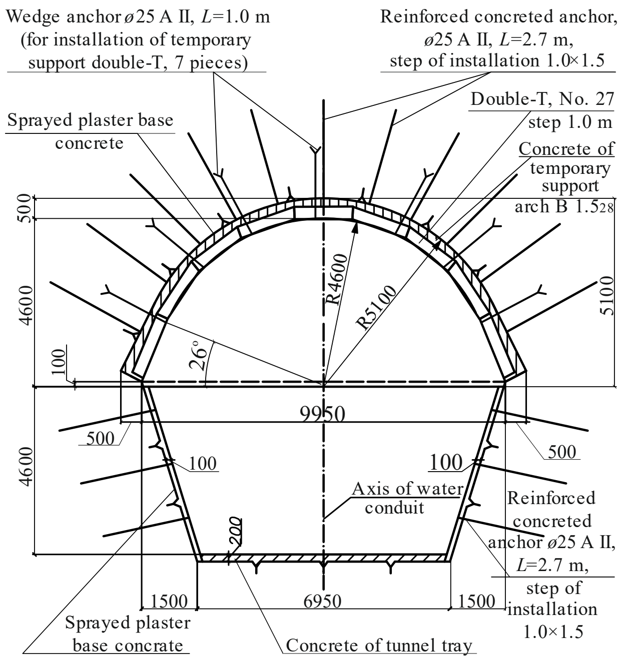

Figure 6. Cross section of the water conduits with upper and lower steps

The contour blast-holes and bottom blast-holes are blasted in a slow manner at intervals of 900, 2000 and 5000 ms. To initiate the charges, the non-electric "Impulse" system is used with special devices UNS-ShK and UNS-PA, which are blasted with a detonating cord from two electric detonators. The use of this method of blasting provides a high level of general and seismic safety when conducting a large-scale explosion with a total consumption of explosives from 97 to 140 kg per a pass (Petrenko, Tiutkin, & Proskurnia, 2016).

When constructing the water supply and discharge mine workings, first of all, the upper step of the specified mine workings is driven and a temporary support is set with the use of a drilling and blasting method (Khomenko, Kononenko, & Myronova, 2013). In addition, a filling cementing of the temporary arch lining is performed.

When cutting the upper step, all the work is carried out in the following sequence. The cutting is conducted with pours of 2.5 – 3.0 m long. A drilling unit UBSH-312A is used for drilling the face. After blasting and airing the mine working, a thorough cleaning of the roof, walls and crown of the face is performed. The rock blasted off by the explosion is cleaned by a rock-loading machine of the LK-1 type, which transports the rock to the area of the installation opening and then unloads it into the bunker. By means of a crawler crane of DEK-50 type, a bunker with rock is raised and unloaded at the upper elevation of the industrial site, from where a bulldozer of DE-53 type moves the rock out of the zone of the crane operation to a distance of 20 m into a temporary reserve. The rock is loaded into motor-vehicle transport by a construction excavator of the E-5015A type with a bucket of 1 m3 capacity, followed by transportation to the dump at a distance of up to 1.0 km.

4. CALCULATION OF ANCHOR FASTENING IN THE CASE OF NEW AUSTRIAN TUNNELING METHOD (NATM) APPLICATION

The water supply and discharge tunnels were built in the rocks with hardness from 4 to 8 by M.M. Protodiakonov scale, which are prone to rock-fall formation. At the same time, a modification of the New-Austrian method (HATM) was applied with the separation of faces into calotte and stross. Moreover, the rock pressure was calculated for the calotte, which was fastened with a combined support, including anchor support, arched support and sprayed plaster base concrete support, and had a dual purpose.

Given the fact that the normative rock pressure (NRP) (DBN V.2.3-7-2010, 2011) is conditioned by the depth of occurring and hardness of the rock, it was necessary to substantiate the efficiency of conducting the technology of mine workings with the use of various types of fastening.

The essence of this technology is in the gradual construction of a combined temporary fastening around the mine working during its driving, which will involve the surrounding rock into the work and strengthen its structure. Thus, an approximate calculation of the anchor was performed from the condition of suspending the block of disturbed rock (V.M. Mostkov), the thickness of which was taken as equal to the roof arch height according to M.M. Protodiakonov:

$$h = \frac{L}{2f}, \quad (1)$$

where:

L – the length of the roof arch span above calotte, which is equal to:

$$L = L_k + 2H_k tg\left(45^\circ - \frac{\varphi}{2}\right), \quad (2)$$

where:

L_k – the length of the bottom calotte part, which is equal to 10.95 m;

H_k – the height of calotte, which is equal to 5.1 m;

φ – the angle of internal rock friction, ranging from 65 to 75 degrees with f = 4 – 8.

Therefore, the mass of a rock block per one anchor is determined by the formula:

$$Q_b = \gamma hac, \quad (3)$$

where:

γ – the average specific weight of overlying rock, which is taken as equal 24 kN/m^3;

a – the step of anchors in the lower part of cross section of mine working, which is determined within the range of $1.5 \le a \le 2.5$ m;

c – the step of anchors along the arc of the upper part of mine working.

The value Q_b, multiplied by an overloading ratio, 1.5, should not exceed the load-bearing capacity of the anchor rod, which is equal to:

$$P = \frac{\pi d^2}{4} R_r^{st}, \quad (4)$$

where:

d – the anchor diameter;

R_r^{st} – the calculated resistance of steel to tensile stress (for steel of A-II class for reinforcement it is 210 MPa).

Having accepted the working diameter of the anchor rod as equal to 25 mm and distance $c = 1.5$ m, the dependence will be obtained for determining the rational step of the anchors:

$$a \le \frac{\pi d^2 R_r^{st}}{6\gamma hc}. \quad (5)$$

For specific engineering and geological conditions of fractured rocks with a hardness of $4 \le f \le 8$ at $c = 1.5$ m, the change in the anchor steps in the lower part of the cross section of mine working is determined by a linear dependence $a = 0.25f + 0.5$. Therefore, the number of anchors located along the arc in the upper part of mine working will vary from 10 to 5 pieces depending on the rock hardness.

The second element of the combined fastening is sprayed plaster base concrete over a grid attached to the anchors. What is more, under its protection the cementation of the surrounding massif is performed by injecting a cement-sand grout into cavities formed by the rock-fall. In the case of fractured rocks with a hardness $4 \le f \le 8$, the thickness of the sprayed plaster base concrete is determined by the formula (V.M. Mostkov):

$$t \ge k_H L_k \sqrt{\frac{\gamma L_k}{f R_r^b m_b}}, \quad (6)$$

where:

k_H and m_b – coefficients by way of which engineering-geological conditions are taken into account in the zone of construction ($k_H = 0.0325$, $m_b = 0.6$);

R_r^b – resistance of sprayed plaster base concrete to tensile stress (for sprayed plaster base concrete of B22.5 class it is 1.15 MPa).

Therefore, the thickness of the sprayed plaster base concrete of temporary fastening of water supply and discharge tunnels at $c = 1.5$ m varies by linear dependence $t = -0.5f + 12$.

When combining the anchors with sprayed plaster base concrete, its thickness should be determined from the condition (V.M. Mostkov):

$$t \ge 0.75c \sqrt{\frac{q}{R_r^b k_H}}, \quad (7)$$

where:

q – the value of pressure from a possible rock-fall in the case of combining with anchors is calculated by the formula $q = 0.37\gamma c$.

Having accepted $c = 1.5$ m, the thickness of sprayed plaster base concrete will be equal to 10 cm, which has been adopted in the design of the work performance.

5. APPLICATION OF STEP METHOD IN MINE WORKINGS CONSTRUCTION

To fasten the arched mine working of the upper step, the temporary support is set from reinforced concrete anchors with a diameter of 25 mm, from reinforcement of A-II class with a length of 2.7 m and the arch made of double – T No.27. Then, when moving the concrete form panel, they are concreted by 3.0 m passes with a lag from the face not more than 2.0 m with the help of a concrete pump located on the near-entrance site.

The filling cementation of temporary support is performed with a lag from the crown of the face at 12 m. The length of the cementation pour is 12 m. For grouting the injection mortar behind the lining in the arch part, the cementing boreholes with a diameter of 52 mm are drilled, which are arranged so that they do not fall into the construction joints. Drilling of boreholes is carried out by a drill rig of the SBU-2M type with a depth of 0.2 m into the rock.

Injection of mortar into each borehole is made through an injector from a tube with a diameter of 38 mm, which is broken out in the walls of the drilled borehole. The finished mortar is fed behind the lining through a flexible rubber-fabric sleeve with a diameter of 50 mm from the ready-mix station set on the near-entrance site. The cementation is performed with a cement-sand grout, when the solution is absorbed up to 1 m^3 per 1 m^2 and more than 1 m^3 per 1 m^2 of the inner surface of the waveguide.

Having finished the injection, the boreholes are eliminated by injecting cement mortar to their full depth.

Having finished the driving of pressure water conduit to the full cross section, a permanent lining is erected with the construction of steel-reinforced concrete tunnels sections, including the metal cladding of the upper part with the concrete structure of the lower part. The structure of tailrace conduit includes a concrete arch in the upper part and a permanent lining of concrete in the lower part. In both cases, the reinforced concrete anchors, sprayed plaster base concrete and filling cementation are also used to strengthen the side walls in the lower part of the tunnels.

When the work on the upper step is finished, the lower step is also cut by means of a drilling and blasting method using borehole charges placed perpendicular to the cross section of the lower step. Drilling of the face is carried out by a drill carriage of SBU-2M type.

The work on cleaning the blasted rock is done in the same order and by the same mechanisms as when cutting the upper step. The temporary support is set from reinforced concrete anchors with a diameter of 25 mm of reinforcement of A-II class with a length of 2.7 m and of the sprayed plaster base concrete with 10 cm of thickness. The boreholes for the anchors are drilled with a hand-feed perforator on a telescopic stand. The sprayed plaster base concrete is sprayed to the walls of the lower step uniformly in two layers with 5 cm thick using a concrete-syringe machine of BM-68U type.

The tray is concreted with 6 m pours. Concrete is laid on the levelled-off and cleaned base with the help of a concrete pump of the BN-1 type and is exposed to vibration action by means of a vibrobatten of the IV-2 type.

6. BASIC INDICATORS OF CONSTRUCTION WORKS PERFORMANCE

In 2017, the Tunnel Construction Department No.7 of KYIVMETROBUD PJSC, when constructing the Dniester PSPS, has performed the following volume of construction works:

– blast-holes and wells have been drilled with a diameter of 40 – 110 mm for 6780 m;

– rock has been developed for 14479.9 m^3;

– cement mortar has been injected for 16700 m^3;

– reinforcement has been assembled for 190.5 ton;

– sprayed plaster base concrete has been applied to the walls of mine workings for 1508.1 m^2;

– concrete has been poured for 5052.9 m^3;

– reinforced concrete has been set for 50.35 m^3;

– cementation work of the space behind the lining has been performed for 964 m.

Such scope of work made it possible to prepare the mine for assembling the hydraulic unit No.4 and practically complete the driving and fastening of the water supply and discharge mine workings for No.5 and No.6 hydraulic units. At the same time, all work is conducted on the basis of an international regulatory document established by a certified BVC Quality Management System that complies with the requirements of ISO 9001:2008 with the certificate number UA 226065/1.

7. CONCLUSIONS

Thus, the article describes a big suite of technology used in Ukraine during the construction of a powerful hydro-technical power facility. The Dniester PSPS will allow to increase the level of power supply of industrial enterprises, agricultural production, as well as large cities and towns. It will also be solved the problem of water regulation on the largest river in Western Ukraine. This will ensure the irrigation of drylands in its southern part, as well as the achievement of the design capacity of the PSPS by 2.72 million kW.

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ОГЛЯД ТЕХНОЛОГІЙ СПОРУДЖЕННЯ ОБ'ЄКТІВ ДНІСТРОВСЬКОЇ ГІДРОАКУМУЛЮЮЧОЇ ЕЛЕКТРОСТАНЦІЇ

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Мета. Виконати огляд технологій спорудження й виявити ефективність українського досвіду будівництва гідроакумулюючої електростанції на р. Дністер у складних інженерно-геологічних умовах зі зведенням великих підземних об'єктів, включаючи шахтні стовбури та гідротехнічні тунелі.

Методика. В роботі розглянуті та проаналізовані основні технологічні способи гідротехнічного будівництва складних великих підземних споруд у скальних породах середньої міцності за шкалою М.М. Протод'яконова із застосуванням спеціального способу опускного колодязя й комбінованого способу ведення буропідривних робіт при проходці гірничих виробок на основі уповільненого і короткоуповільненого підривання. Розрахунок анкерів при проходці водоводів виконувався з умови підвішування блоку порушеної породи, товщина якого приймалася рівною висоті склепіння обвалення за М.М. Протод'яконовим. Розрахунок параметрів набризгбетону проводився також за теорією В.М. Мосткова.

Результати. Виконано аналіз сучасного стану досліджень, теоретичних положень і світової практики будівництва гідроакумулюючих станцій, що свідчить про високий потенціал даного виду енергетичних об'єктів. Обґрунтовано ефективність підземного гідротехнічного будівництва Дністровської станції. Представлені результати застосування комплексу гірничопрохідницьких і будівельних методів та технологічного обладнання для спорудження горизонтальних і відвідних водоводів, дренажних штолень та вертикальних шахт для гідроагрегатів у складних інженерно-геологічних умовах. В результаті виконаних аналітичних досліджень обґрунтований комбінований метод створення анкерного набризгбетонного кріплення при проходці водоводів, що є найбільш раціональним для інженерно-геологічних умов підвищеної складності.

Наукова новизна. Для умов будівництва гідроакумулюючої електростанції на р. Дністер визначено ефективність методу опускного колодязя в тиксотропної сорочці при будівництві в слабких ґрунтах. Обґрунтовано поетапний комбінований метод створення анкерного й набризгбетонного кріплення при проходці водоводів.

Практична значимість. Обґрунтовано й впроваджено найбільш раціональні способи ведення комплексу гірничобудівельних робіт, що дозволяють здійснювати будівництво складного гідроакумулюючого об'єкта потужністю понад 2.0 млнкіловат, що забезпечує суттєве підвищення енергоозброєності західного регіону України.

Ключові слова: *гідроакумулююча електростанція, дренажна штольня, підхідна штольня, шахти гідроагрегатів, водоприймач*

ОБЗОР ТЕХНОЛОГИЙ СООРУЖЕНИЯ ОБЪЕКТОВ ДНЕСТРОВСКОЙ ГИДРОАККУМУЛИРУЮЩЕЙ ЭЛЕКТРОСТАНЦИИ

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Цель. Выполнить обзор технологий сооружения и выявить эффективность украинского опыта строительства гидроаккумулирующей электростанции на р. Днестр в сложных инженерно-геологических условиях с возведением крупных подземных объектов, включая шахтные стволы и гидротехнические тоннели.

Методика. В работе рассмотрены и проанализированы основные технологические способы гидротехнического строительства сложных крупных подземных сооружений в скальных породах средней крепости по шкале М.М. Протодьяконова с применением специального способа опускного колодца и комбинированного способа ведения буровзрывных работ при проходке горных выработок на основе замедленного и короткозамедленного взрывания. Расчет анкеров при проходке водоводов выполнялся из условия подвешивания блока нарушенной породы, толщина которого принималась равной высоте свода обрушения по М.М. Протодьяконову. Расчет параметров набрызгбетона производился также по теории В.М. Мосткова.

Результаты. Выполнен анализ современного состояния исследований, теоретических положений и мировой практики строительства гидроаккумулирующих станций, свидетельствующий о высоком потенциале данного вида энергетических объектов. Обоснована эффективность подземного гидротехнического строительства Днестровской станции. Представлены результаты применения комплекса горнопроходческих и строительных методов и технологического оборудования для сооружения горизонтальных и отводящих водоводов, дренажных штолен и вертикальных шахт для гидроагрегатов в сложных инженерно-геологических условиях. В результате выполненных аналитических исследований обоснован комбинированный метод создания анкерной набрызгбетонной крепи при проходке водоводов, являющийся наиболее рациональным для инженерно-геологических условий повышенной сложности.

Научная новизна. Для условий строительства гидроаккумулирующей электростанции на р. Днестр определена эффективность метода опускного колодца в тиксотропной рубашке при строительстве в слабых грунтах. Обоснован поэтапный комбинированный метод создания анкерной и набрызгбетонной крепей при проходке водоводов.

Практическая значимость. Обоснованы и внедрены наиболее рациональные способы ведения комплекса горностроительных работ, позволяющие осуществлять строительство сложного гидроаккумулирующего объекта мощностью более 2.0 млн киловатт и обеспечивающего существенное повышение энерговооруженности западного региона Украины.

Ключевые слова: *гидроаккумулирующая электростанция, дренажная штольня, подходная штольня, шахты гидроагрегатов, водоприемник*

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