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Development of the software and technical complex of the high-precision satellite positioning system in the conditions of open pit mining processes

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ABSTRACT
The article presents technical solutions for the implementation of a high-precision satellite positioning system when performing mine surveying in an open pit. A system was put into commercial operation at one of the fields of JSC "Sokolovsko-Sarbayskoe mining and processing production association" (JSC "SSGPO") this year. The project was funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan through grants for scientific and technical projects 2018–2020 and was co-financed by a private partner, JSC "SSGPO". All work was carried out jointly with the Subsidiary Limited Liability Company "Institute of Space Engineering and Technology". The technology of differential correction of GNSS signals in the form of base stations of differential correction (BSDC) allows solving the problems of high-precision satellite positioning. The main task assigned to the continuously operating base station is the collection of code and phase data from GPS/GLONASS satellites and the distribution of this data to users (services of JSC "SSGPO" and specialists of contracting organizations performing mine surveying and geodetic work at the field). Development of a mobile module and the rationale for its inclusion in the BSDC is provided in this work.

Keywords: *base station for differential correction (BSDC), active repeater, ultrashort waves (VHF), Global Navigation Satellite Systems (GNSS), pit.*

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Introduction

The base station for differential correction (BSDC) refers to the systems of receiving and processing navigation signals. BSDC is a land-based stationary station for receiving and processing GLONASS/GPS/BeiDou signals, includes software support (SS) for processing satellite measurements and a complex of radio-electronic and technical means [1, 2].

The base station of differential correction is intended for automated reception of navigation signals, processing, storage, and provision of navigation data to consumers in the served area, as well as transmission of navigation data and service information to the differential correction center (CDC).

SS BSDC is intended for decoding the differential corrections stream, processing navigation data and inverse coding of the differential corrections stream for transmission via GSM and VHF channels to consumers of correcting information. CDC software

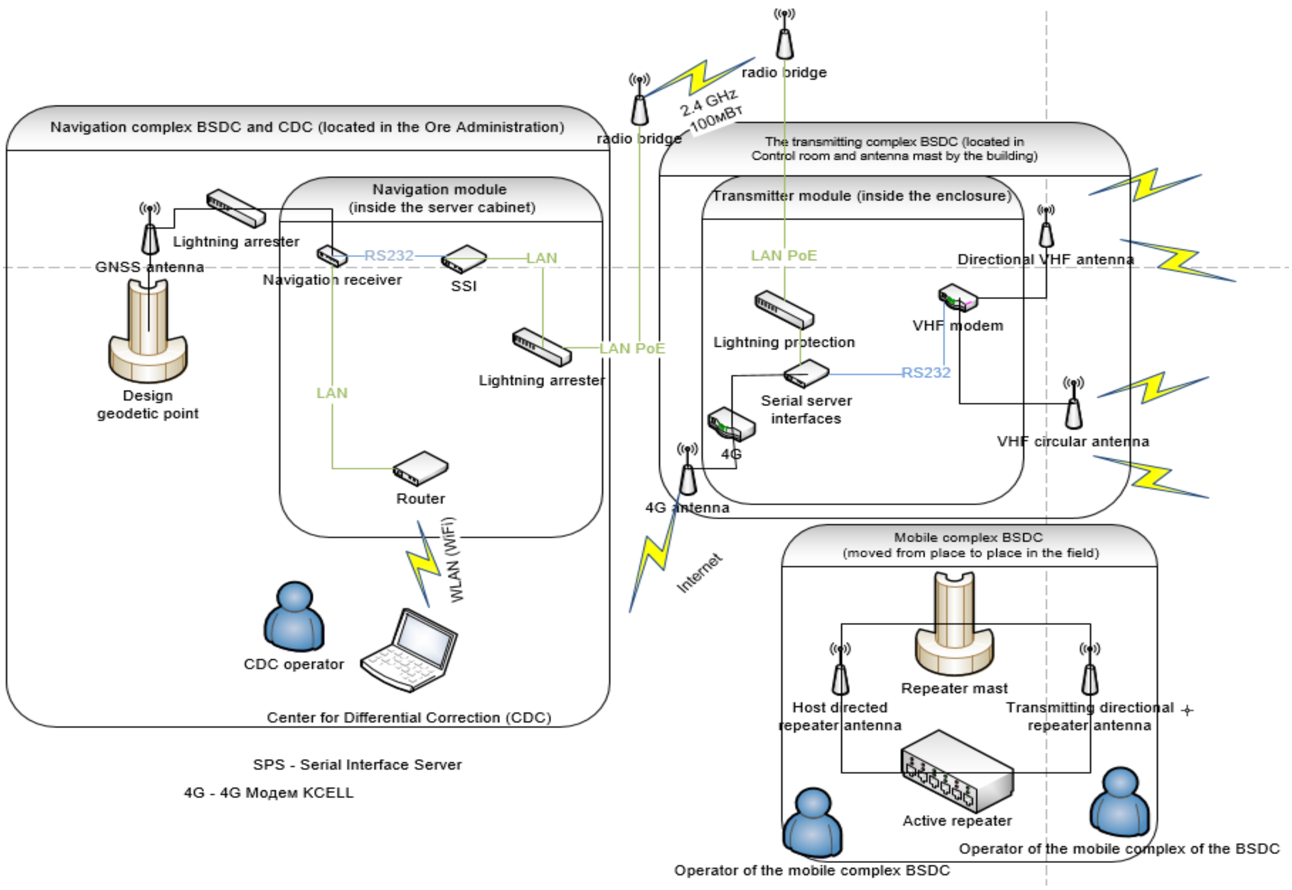

Figure 1 - Location of the BSDC complexes. **Mobile complex BSDC**

is designed for remote monitoring of the BSDC state, control of operating modes, and control of the BSDK operating modes.

The purpose of the BSDK creation is the formation and transmission of differential corrections, which are used by GPS receivers (rovers) of the Kacharsky pit of JSC "SSGPO".

BSDC can be divided into 3 interconnected complexes (navigation, transmitting and mobile complexes), containing the following main types of equipment:

- ✓ navigation equipment;
- ✓ computing equipment;
- ✓ telecommunication equipment;
- ✓ other equipment and devices.

The location of the BSDC complexes is shown in the figure 1.

The mining enterprise developed working design documentation (WDC) for the base station of differential correction (BSDC) prior to the start of the project. In general, the developed WDC includes: the BSDC specification; drawing of the geodetic point on which the base station is installed; BSDC operation manual and BSDC test program.

The development of a mobile complex is further considered in detail, taking into account the conditions of mine surveying at the Kacharsky pit. The manual for the operation of the mobile complex BSDC is part of the general manual for the operation of the BSDC. The central element of BSDC is the repeater.

An active repeater is a transmitting and receiving radio technical device, which is located at intermediate points of radio communication lines, the function of which is to amplify the received signals and their further transmission [3]. The equipment of the mobile complex BSDC in general is shown in Figure 2.

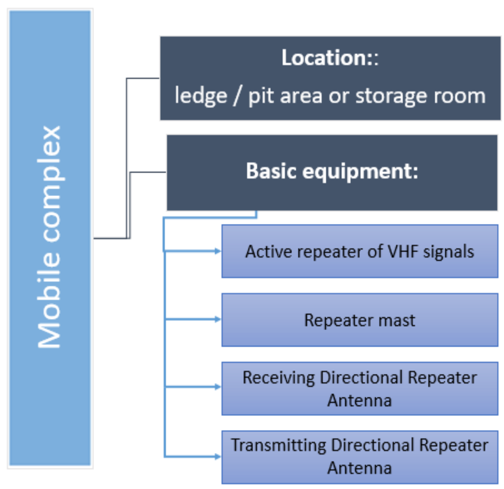

Figure 2 - Equipment of the mobile complex BSDC

Hytera RD625 analog-to-digital repeater was selected as a VHF signal repeater. Built-in mini duplex and power supply allow up to 25W output power. This functional design of the RD625 combines in one housing: a transceiver, a power supply, and a duplexer (see Figure 3) [4].

The power supply unit integrated into the RD625 allows for autonomous charging of the backup battery. Its output voltage is 13.6V ± 15%, and its output system voltage is 90 ~ 264VAC. If the input voltage is lost, the repeater automatically starts switching over to operation from the backup battery, without breaking the connection. RDAC software application allows to increase the efficiency of maintenance and control of the repeater and is used for its diagnostics and control [4].

Figure 3 - Hytera RD625 repeater

This type of repeater proved to be quite heavy and required a serious wind-resistant mast. Therefore, a folding design of the tripod-type repeater mast was developed. In order not to mount such structure every day, it was installed on a transport trolley (trailer), which made it possible to carry out its mobility.

The repeater with frequency transfer f1/f2 is intended for radio coverage of shadow zones by creating a secondary radio zone at frequency f2. This repeater has been tuned to operate with a VHF input signal at a frequency of (f1) 408.00 MHz, and its output frequency (f2) is 411.00 MHz.

As a result, the mobile repeater included: folding telescopic mast, directional antennas with cables and connectors - 2 pcs, rotary nodes - 2 pcs, a protective box, the repeater itself, a power battery, wire extensions with tensioners and anchors - 3 pcs.

Orientation and setting the tilt of the antennas relative to the horizon, special mechanical tilt units 3 and 4 are made for fixing the antennas to the mast (see Figure 4). The nodes provide antenna tilt + 30°, + 15°, 0°, -15°, -30°, as well as the necessary resistance to wind loads.

To change the angle of inclination of the antennas, it is required to unscrew the fixing screws shown in Figure 4, turn and tilt the plate with the antenna to the desired angle and torque down the screws.

To set the required orientation of the antennas, it is needed to loosen the upper and lower nuts of the tilt unit, shown in Figure 5a. While supporting the antenna and node, the antennas must be turned towards the control tower and secondary area, respectively. At the end of the procedure, tighten the nuts back.

a) tilt node -3 of receiving antenna -2 in position + 15°

b) tilt unit -4 of the transmitting antenna -7 in the 0° position

Figure 4 - Special mechanical tilt units 3 and 4

To link antennas to the repeater, the antenna cable of the receiving antenna is connected to the N-type connector on the repeater body, see 5b. The antenna cable of the transmitting antenna is joined to the N-type connector on the repeater body. If the length of the receiving antenna cable is not enough, an extension cable adapter is used.

a) receiving antenna at the top and transmitting antenna at the bottom of the mast

b) repeater with a power supply battery in a protective box

Figure 5 - Repeater and VHF antennas

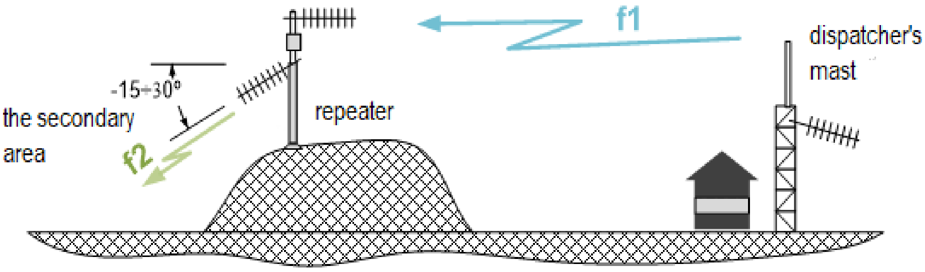

Figure 6 - Orientation of antennas when installing on dumps

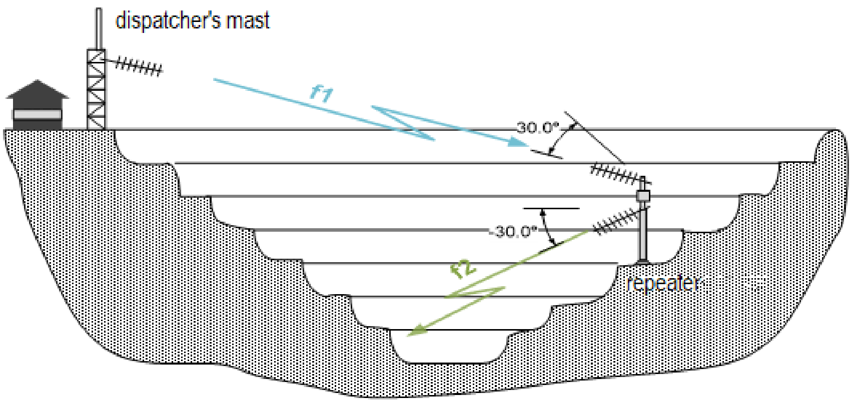

Figure 7 - Orientation of antennas when installed in a pit

It is important to remember that turning on and supplying power to the repeater - 20 by pressing the button -28 (see Fig.5b) is allowed after connecting the antenna cables and the power must be turned off before disconnecting the antenna cables.

Antenna orientation in various operating modes in open pit conditions

If the working area is located on the surface of the pit behind the dumps, the receiving antenna of the repeater (upper) should be oriented towards the control tower using tilt nodes 3 and 4. The secondary radio coverage area (at frequency f2) will be provided in the sector of the transmitting (lower) directional antenna. The width of the secondary sector will be approximately 35°. The length of the secondary radio coverage area can be from 3 to 5 km, depending on the height of the repeater antennas above ground level.

If the repeater is far away from the control tower, the repeater should be located at a height (see Figure 6).

When placing the repeater in a pit, fix the antennas at tilt nodes 3 and 4 using locking screws 23 in the position + 30o and - 30o, respectively. The secondary radio coverage area (at frequency f2) will be located at the bottom of the pit (see Figure 7).

Conclusion

The use of global navigation satellite systems (GNSS) in open-pit conditions has some specific features. The design of the pit walls in the extreme position with steep slopes, as well as a constant increase in the pit depth, entails not only a decrease in the number of visible satellites but also an increase in sighting angles, which leads to an increase in the DOP coefficient (geometric decrease in accuracy) [5]. One of the possible ways to solve this problem was the development of a mobile complex BSDC, in particular, the use of an active repeater.

The significance of this project on a national scale consists of providing high-precision positioning of the territory of a mining enterprise and allows solving two main problems of open pit mining hereafter: increasing labor productivity through the introduction of digital technologies and significantly increasing its safety [6-8]. Implementation of the developed high-precision positioning system at the Kacharsky field will allow its use at other mining enterprises in Kazakhstan.

Conflicts of interest. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Ашық тау-кен жұмыстары жағдайында жоғары дәлдікті жерсеріктік жайғастыру жүйесінің бағдарламалық-техникалық кешенін әзірлеу

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ТҮЙІНДЕМЕ

Мақалада ашық карьерде маркшейдерлік жұмыстарды орындау кезінде жоғары дәлдікті жерсеріктік жайғастыру жүйесін іске асыруға арналған техникалық шешімдер ұсынылған. Биыл бұл жүйе "ССКӨБ"АҚ кен орындарының бірінде өнеркәсіптік пайдалануға енгізілді. Жобаны Қазақстан Республикасы Білім және ғылым министрлігінің (ҚР БҒМ) Ғылым комитеті 2018-2020 жылдарға арналған ғылыми-техникалық жобаларға гранттар желісі бойынша қаржыландырды және оны «Соколовско-Сарбайское тау-кен байыту өндірістік бірлестігі» АҚ ("ССКӨБ"АҚ) жекеменшік серіктестігі қосымша қаржыландырды. Барлық жұмыстар "Ғарыштық техника және технологиялар институты" Еншілес жауапкершілігі шектеулі серіктестікпен (ЕЖШС) бірлесіп орындалды». Жоғары дәлдікті жерсеріктік жайғастыру есептерін шешуге мүмкіндік беретін технология - ДТБС-дифференциалды түзетудің базалық станциялары ҒНЖЖ түріндегі сигналдарын дифференциалды түзету технологиясы болып табылады. Үздіксіз жұмыс істейтін базалық станцияға жүктелген негізгі міндет - GPS/ГЛОНАСС спутниктері бойынша кодтық және фазалық деректерді жинау және осы деректерді пайдаланушыларға ("ССКӨБ" АҚ қызметтері мен кен орнында маркшейдерлік-геодезиялық жұмыстарды орындайтын мердігер ұйымдардың мамандарына) тарату. Бұл жұмыста мобильді модульдің әзірлемесі және оны ДТБС құрамына қосудың негіздемесі келтірілген.

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Разработка программно-технического комплекса системы высокоточного спутникового позиционирования в условиях открытых горных работ

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АННОТАЦИЯ

В статье представлены технические решения для реализации системы высокоточного спутникового позиционирования при выполнении маркшейдерских работ на открытом карьере. В этом году данная система введена в промышленную эксплуатацию на одном из месторождений АО «Соколовско-Сарбайское горно-обогатительное производственное объединение» (АО «ССГПО»). Проект был профинансирован Комитетом науки Министерства образования и науки Республики Казахстан (МОН РК) по линии грантов на научно-технические проекты на 2018–2020 гг. и прософинансирован частным партнером АО «ССГПО». Все работы выполнялись совместно с ДТОО «Институт космической техники и технологий». Технологией, позволяющей решать задачи высокоточного спутникового позиционирования, является технология дифференциальной коррекции сигналов ГНСС в виде базовых станций дифференциальной коррекции (БСДК). Основная задача, возложенная на непрерывно действующую базовую станцию - это сбор кодовых и фазовых данных по спутникам GPS/ГЛОНАСС и распределение этих данных пользователям (службам АО «ССГПО» и специалистам подрядных организаций, выполняющих маркшейдерско-геодезические работы на месторождении). В данной работе приводится разработка мобильного модуля и обоснование его включения в состав БСДК.

Ключевые слова: *базовая станция дифференциальной коррекции (БСДК), активный ретранслятор, ультракороткие волны (УКВ), Глобальные навигационные спутниковые системы (ГНСС), карьер.*

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Литература

[1] Huaan Fan. Direct solutions of three-dimensional coordinate transformation parameters//Interexpo Geo-Siberia. 2009. No.1. URL: https://cyberleninka.ru/article/n/direct-solutions-of-3d-coordinate-transformation-parameters (date of the application: 30.07.2020)

[2] Galiyev S.Zh., Dovzhenok A.S., Kol'ga A.D., Uteshov E.T. Digitalization and the potential for improving the design and planning of mining operations in open cast mining / N e w s of the national academy of sciences of the republic of Kazakhstan series of geology and technical sciences ISSN 2224-5278 Volume 1, Number 439 (2020), 146 – 154 https://doi.org/10.32014/2020.2518-170X.18

[3] Большая советская энциклопедия «Словари и энциклопедии на Академике». Интернет ресурс: https://dic.academic.ru/dic.nsf/bse/127310/%D0%A0%D0%B5%D1%82%D1%80%D0%B0%D0%BD%D1%81%D0%BB%D1%8F%D1%82%D0%BE%D1%80 (дата обращения: 7.10.2020).

[4] Официальный сайт инженерно-технической компании «АЛСИ-АЗИЯ-ПЕЙДЖ» https://www.radio.com.kz/. Интернет ресурс: https://www.radio.com.kz/products/6/1928/ (дата обращения: 10.08.2019)

[5] Горев Павел Александрович, Костиков Владимир Григорьевич Система высокоточной спутниковой навигации для управления процессами открытых горных работ // ГИАБ. 2015. №9. URL: https://cyberleninka.ru/article/n/sistema-

vysokotochnoy-sputnikovoy-navigatsii-dlya-upravleniya-protsessami-otkrytyh-gornyh-rabot (дата обращения: 14.10.2020).

[6] Baltiyeva, A.; Shamganova, L.; Raskaliyev, A.; Kuzmenko, S. Telecommunication decisions for high-precision satellite positioning on the Kacharsky pit // 19th International Multidisciplinary Scientific Geoconference SGEM 2019. Conference proceeding volume 19. Informatics, geoinformatics and remote sensing issue 2.2 – Albena, 2019, 333-340 p. DOI: 10.5593/sgem2019/2.2/S09.041 https://www.sgem.org/index.php/elibrary-research-areas?view=publication&task=show&id=5505 (IF 0,25)

[7] Кузьменко С. В., Шамганова Л. С., Ахмедов Д. Ш., Балтиева А. А. Информационно-навигационное обеспечение горных работ на карьерах Соколовско-Сарбайского горно-обогатительного производственного объединения. Горный журнал, 2018, No. 5, ISSN 00172278, стр. 27-32, DOI:10.17580/gzh.2018.05.11. https://www.rudmet.ru/journal/1722/article/29555/ (IF 0,38)

[8] Buktukov N.S., Gumennikov E. S., Asanov A.A. Mashataeva G. A. New solutions to the problems of stripping of ore bodies using inclined workings driven downward in conditions of increased water cut. Kompleksnoe Ispol’zovanie Mineral’nogo Syr’a. = Complex Use of Mineral Resources = Mineraldik Shikisattardy Keshendi Paidalanu. - 2020. № 4 (315), pp. 25-32. https://doi.org/10.31643/2020/6445.33

Reference

[1] Huaan Fan. Direct solutions of three-dimensional coordinate transformation parameters//Interexpo Geo-Siberia. 2009. No.1. URL: https://cyberleninka.ru/article/n/direct-solutions-of-3d-coordinate-transformation-parameters (date of the application: 30.07.2020) (In Eng.).

[2] Galiyev S.Zh., Dovzhenok A.S., Kol’ga A.D., Uteshov E.T. Digitalization and the potential for improving the design and planning of mining operations in open cast mining / N e w s of the national academy of sciences of the republic of Kazakhstan series of geology and technical sciences ISSN 2224-5278 Volume 1, Number 439 (2020), 146 – 154 https://doi.org/10.32014/2020.2518-170X.18 (In Eng.).

[3] Bol'shaya sovetskaya entsiklopediya «Slovari i entsiklopedii na Akademike». [Great Soviet Encyclopedia "Dictionaries and Encyclopedias on Academician"]. (date of access: 10/07/2020). Internet resource: https://dic.academic.ru/dic.nsf/bse/127310/%D0%A0%D0%B5%D1%82%D1%80%D0%B0%D0%BD%D1%81% D0% BB% D1% 8F% D1% 82% D0% BE% D1% 80 (In Rus).

[4] Ofitsial'nyy sayt inzhenerno-tekhnicheskoy kompanii [The official website of the engineering and technical company] "ALSI-ASIA-PAGE" https://www.radio.com.kz/. Internet resource: https://www.radio.com.kz/products/6/1928/ (date of access: 10.08.2019). (In Rus).

[5] Gorev Pavel Alexandrovich, Kostikov Vladimir Grigorievich Sistema vysokotochnoy sputnikovoy navigatsii dlya upravleniya protsessami otkrytykh gornykh rabot [High-precision satellite navigation system for control of open-pit mining processes] // GIAB. 2015. No. 9. URL: https://cyberleninka.ru/article/n/sistema-vysokotochnoy-sputnikovoy-navigatsii-dlya-upravleniya-protsessami-otkrytyh-gornyh-rabot (date of access: 10/14/2020). (In Rus).

[6] Baltiyeva, A.; Shamganova, L.; Raskaliyev, A.; Kuzmenko, S. Telecommunication decisions for high-precision satellite positioning on the Kacharsky pit // 19th International Multidisciplinary Scientific Geoconference SGEM 2019. Conference proceeding volume 19. Informatics, geoinformatics and remote sensing issue 2.2 – Albena, 2019, 333-340 p. DOI:10.5593/sgem2019/2.2/S09.041 https://www.sgem.org/index.php/elibrary-research-areas?view=publication&task=show&id=5505 (In Eng.).

[7] Kuzmenko S. V., Shamganova L. S., Akhmedov D. Sh., Baltiyeva A. A. Informatsionno-navigatsionnoye obespecheniye gornykh rabot na kar'yerakh Sokolovsko-Sarbayskogo gorno-obogatitel'nogo proizvodstvennogo ob"yedineniya. [Information and navigation support of mining operations at the open pits of the Sokolovsko-Sarbaisky mining and processing production association]. *Gornyy zhurnal = Mining Journal*, 2018, No. 5, ISSN 00172278, pp. 27-32, DOI:10.17580/ gzh.2018.05.11. https://www.rudmet.ru/journal/1722/article/29555/ (In Rus).

[8] Buktukov N.S., Gumennikov E. S., Asanov A.A. Mashataeva G. A. New solutions to the problems of stripping of ore bodies using inclined workings driven downward in conditions of increased water cut. Kompleksnoe Ispol’zovanie Mineral’nogo Syr’a. = Complex Use of Mineral Resources = Mineraldik Shikisattardy Keshendi Paidalanu. - 2020. № 4 (315), pp. 25-32. https://doi.org/10.31643/2020/6445.33 (In Eng.).