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IMPROVING THE EFFICIENCY UNDERGROUND MINING OF COAL BEDS IN DIFFICULT MINING AND GEOLOGICAL CONDITIONS

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ABSTRACT

The main goal of the research is to improve the efficiency of underground coal mining in difficult geological conditions based on an integrated approach to the technological schemes designing, and the feasibility study of space-planning decisions. In conducting the research, the authors used a complex method, including synthesis and analysis of the theory and practice of the development of coal beds using underground methods; the analysis of the results of field studies of the underground working conditions in the high rock pressure areas; the experimental and analytical studies of the effect of high rock pressure areas on the state of excavation workings in the lavas at various parameters of technological schemes; computer data processing. The specifics of mining and geological conditions of mining operations in the Russian mines were analyzed. The issues of ensuring the efficiency of underground mining and a choice of rational space-planning decisions in complex mining and geological conditions were considered. Based on the computer modelling, the cost-effectiveness of different options for the development of mining operations in the conditions of the "Alardinskaya" mine was estimated. The necessity of taking into account the production effectiveness of the reserve extraction in the process of assessing the resource base of the mining enterprises was shown. The recommendations for the sustainable development of the coal-mining companies, taking into account the resource base efficiency, were given. The study results obtained can be used in the design of new mines and substantiation of space-planning solutions in underground mining of coal beds.

Keywords: underground mining, coal deposits, resource base, long faces, complex mining and geological conditions, advanced technologies, sustainable development

1. INTRODUCTION

The Long-term Program for the Development of the Russian Coal Industry for the Period up to 2030 (hereinafter - the Program), approved in 2014 by the Russian Federation Government Decree, is aimed at creating conditions for Russian coal companies for the stable supply of coal and its derivative products to the domestic market, as well as the development of their export potential (Long-Term Program for the Development of the Russian Coal Industry for the Period until 2030). The presence of huge (2nd place in the world) coal reserves, which at current production levels will last for 600 years, serves as one of the competitive advantages of the Russian coal companies. At the same time, the number of problems of the domestic coal industry that do not allow to fully realize competitive advantages, includes an increase in the proportion of underground coal mining performed in adverse geological conditions (Shmatko, 2011). Over the past ten years, the average depth of the bed mining in mines increased by 12%, reaching 441 meters in 2012. Almost all (90.8%) developed coal beds are dangerous at least by one of the factors (rock bursts, sudden outbursts of coal and gas, prone to spontaneous combustion, having high gas category, etc.), while 74% of mines are dangerous by two or more factors concurrently (Long-Term Program for the Development of the Russian Coal Industry for the Period until, 2030). The noted increasing complexity of mining conditions in the mines is an inevitable consequence of low efficiency of the resource base of Russian coal-mining mines. Of the balance reserves of existing enterprises about 1/3 make up the unfavorable reserves, and 1/10 - very unfavorable reserves. The "high-tech" reserves favorable for mining are very unevenly distributed across the production regions. The main areas of their concentration are the Kuznetsk and Kansk-Achinsk basin, comprising about 70% of all Russian favorable reserves (Strok& Gorbachev, 1995). The majority of the industry mines have the reserves unfavorable for development. It should be noted that due to the wide spread of the long-pillar method in underground coal mining in Russia (Zavolokin, 2008), the feasibility and effectiveness of its application in most cases determines the feasibility of the reserves categorizing as favorable or unfavorable for mining.

Furthermore, it is necessary to take into account the increasing complexity of the reserves mining conditions with the development of underground mining, which is due to the complexity of mining and geological conditions with increasing depth of mining operations, and the associated increase in gas content of the mined beds and intensity of rock pressure on the one hand, and on the other - the complication of the mine engineering situation in the bowels due to the formation of discharge and increased rock pressure areas (IRP), the parameters of which are undergoing significant changes in time and space with the development of mining activities (Demin, *et al*. 2012).

The mine engineering situations in the mines which perform mining of the reserves of contiguous gas-bearing formations prone to spontaneous combustion, using a pillar mining system, are especially complex. The use of modern high-performance systems in these circumstances has determined the necessity of leaving the indestructible chain pillars between the productions areas, providing reliable isolation of worked-out areas and minimizing the effect of actual mining on the condition of

zonal whole workings fixed with roof bolting. However, the mining of adjacent coal beds in such conditions is characterized by the formation of high rock pressure areas, in which the location of clearing and whole workings is associated both with an increased risk of dynamic and gasdynamic phenomena and with extreme difficulty of maintaining the operational status of zonal whole workings for the duration of their service.

Figure-1 shows the basic form of loss of stability of excavation workings identified by the mine observations in terms of the Kuznetsk coal basin. The significant direct cost of repairs or, if repair was impossible, the costs of further parallel mining for the preparation of a new extraction pillar, as well as significant damage from prolonged downtime of efficient equipment resulted in the working destruction (Guidelines for the Rational Layout, Protection and Maintenance of Mining at the Mines of the USSR; Kazanin and Zadavin, 2007). The analysis of the cases reviewed showed that the highest costs resulting from the working destruction took place at the location of excavation workings in the zone of influence of overworked or underworked bed, namely in the high rock pressure area above or below the coal pillars or edge portions of the array.

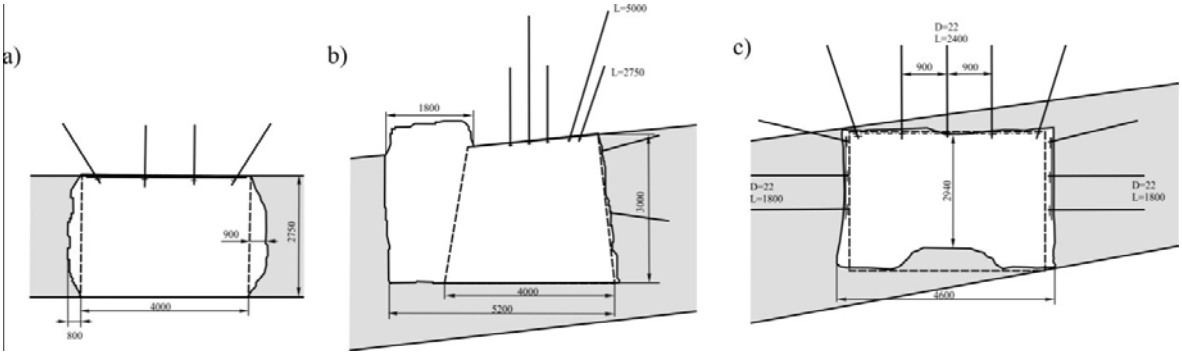

Figure-1. Typical forms of loss of stability of mine workings in the conditions of Kuzbass a) Coal extraction from the working boards; b) destruction of the coal in the edge portion of the bed; c) soil swelling and coal extraction.

A large number of scientific studies were devoted to the issues of the efficient mining of reserves in difficult mining and geological conditions and to the provision of sustainability of zonal development workings in high rock pressure areas. However, the analysis of the experience of the reserve mining in such circumstances shows a significant decrease in technical performance and mining safety indicators (Strok& Gorbachev 1995;Remezov&Klimov 2015). In this connection, the problem of the effective reserve mining in difficult geological conditions remains particularly relevant for the Russian coal industry.

The authors of the article propose the use of an integrated approach to the selection and justification of space-planning decisions, linking into one the issues of the rock mass controlling, controlling of gas emission in mine workings and ensuring geodynamic and fire safety of mining operations with a mandatory evaluation of the effectiveness of possible options for the development of mining operations.

2. METHOD

In conducting the research, the authors used a complex method, including synthesis and analysis of the theory and practice of development of coal beds using underground methods; the analysis of the results of field studies of the underground working conditions in the high rock pressure areas; the experimental and analytical studies of the effect of high rock pressure areas on the state of excavation workings in the lavas at various parameters of technological schemes; computer data processing.

The consideration of natural resources as an economic category is of fundamental importance for the production efficiency improvement (Reshetov 2006). The influence of geological conditions of deposits and their areas on the adoption of cost-effective space-planning decisions may be considered on the example of the “Alardinskaya" mine of QMD OJSC “Yuzhkuzbassugol”. Characteristics of the main mined beds and the typical geological section is shown in Table 1 and Figure 2 respectively.

Several options of the mining operations development by beds are possible in such mining and geological conditions of the "Alardinskaya" mine. The availability of high-tech coal reserves is the basis to focus on the implementation of schemes in "mine-layer" and "mine-lava" versions (Kuznetsov & Groshenkova, 2003; Peng, 2008).

Version 1. It provides for consistent downward bed working. The reserve mining using the "mine-lava" scheme is also possible. In this case, only one bed is simultaneously worked out. The mining of bed *1* is recommended without leaving the interpillar blocks.

Table-1. Characteristics of coal beds (Alardinskaya mountain area -300 m).

Bed	Capacity, m	Density, t/cu.m	Grade	Distance between the beds, m	Danger by dynamic phenomena	Coal tendency to spontaneous combustion
1	1.22-1.86	1.41	K, OS	-	Threatened by rock bursts	Prone to spontaneous combustion
3-3[a]	3.74-5.26	1.42	KS, TS	33-45	Threatened by rock bursts and sudden outbursts	Very prone to spontaneous combustion
6	6.64-9.24	1.40	KS, TS	28-40	Threatened by rock bursts and sudden outbursts	Prone to spontaneous combustion

Version 2. Simultaneous mining of beds *1* and *3-3a* with the delay in mining works on *3-3a* bed. The time gap between mining of *1* and *3-3a* beds for less than 5 years provides for the protective effect of the worked areas of the bed *1* with respect to *3-3a* bed.

Version 3. Primary mining of the *3-3a* bed reserves followed by mining of reserves from the beds *1* and *6*.

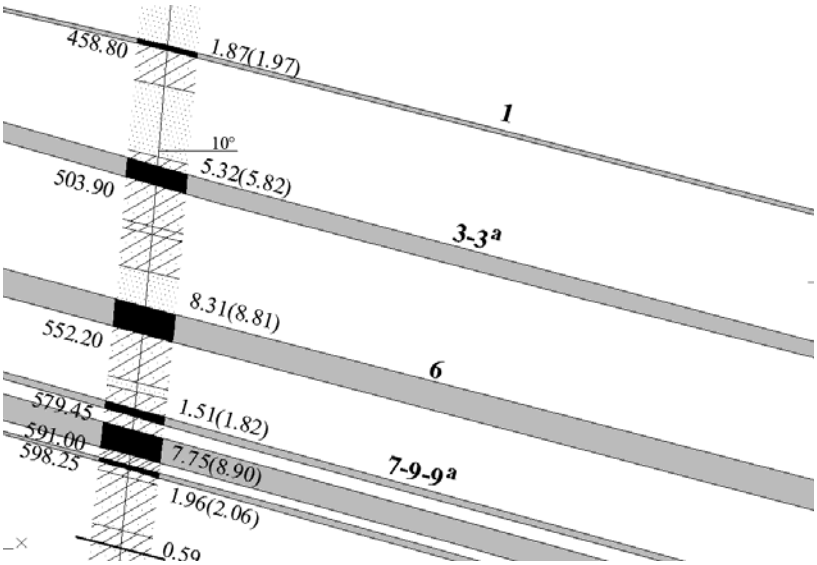

Figure-2. Fragment of the geological section (VIII r.e.l., Alardinskaya mine).

It should be noted that the versions considered can be implemented in compliance with the above principles with the mining of the reserves not from the whole bed of the mine field, but from the excavation sites of considerable size (including several extraction pillars).

From the standpoint of geomechanics and dynamic security in mining of the series of beds threatened by rock bursts, the reserves mining should begin with the least threatened bed. In this case, the bed 1 may be recommended for primary mining because it underlays at lesser depth and has the smallest capacity. However, this bed is the least productive by capacity and its mining will lead either to a reduction of the mine production capacity with respect to the designed one, or to the need for simultaneous operation of several working faces, which reduces the concentration of mining operations and requires the acquisition of multiple sets of costly pollution control equipment and excludes the reserve mining according to the "mine-lava" scheme (Kazanin, *et al*. 2015).

At the same time, the implementation of the Option 3 provides for a mine operation, according to the "mine-lava" scheme allowing to reach full production capacity in a short time by involving of powerful productive bed 3-3a in mining.

The use of the Option 3 requires simultaneous mining of two beds, which provides further reduction of the operations concentration (as compared with the Options 1 and 2), and is characterized by significantly higher initial capital expenditures.

It should be noted that in practice in the “Alardinskaya” mine conditions the mining options 1 and 3 were implemented within different excavation blocks and at different times. The implementation of the Option 3 was associated with the occurrence of incidents involving the destruction of the edge parts of interpillar coal block and the sides of the zonal development working and the

need for significant costs for the preliminary discharge of rock pressure from 3-3a bed, as well as significant damage associated with long-term (over 30 days) downtime of high-performance cleaning equipment. Implementation of the Option 1 was characterized by relatively high technical and economic indicators.

To assess the cost-effectiveness of the reserve mining options under consideration the simulation was performed by converting the time-spaced costs and benefits to the cash flows and the calculation of the options performance parameters based on these flows (Kushnerov, *et al.* 2005). The simulation was performed for the conditions of the excavation block of the "Alardinskaya" mine.

3. RESULTS

The results of economic and mathematical modeling are presented in Table-1 and Figure-3. Table-2 shows the indicators of economic efficiency of the options under consideration.

Table-2. The indicators of the economic efficiency of the options under consideration.

Indicator	Option			
	1	2	3	3 A
NPV, mln. rub.	1143	1092	498	1406
T_{OK}, years	6.8	7	8.5	6.2
II	1.35	1.27	1.17	1.47
GNI	17.5	16.2	13.5	19

As Table-1 shows, the Option 3A demonstrates the best performance, but this option is the optimistic scenario of the Option 3 development for the given conditions, as it provides for the absence of incidents and emergencies, as well as long-term downtime of high-performance equipment, which have taken place in practice. The Option 3 is a realistic one for these conditions. Its indicators are calculated taking into account the equipment downtime duration and damage that occurred in the conditions of the "Alardinskaya" mine. As shown in Table-2 and graphs (Figure-3), the Option 3 shows the worst performance among the options under consideration. Thus, the calculation of technical and economic parameters for the Option 3 A is incorrect due to the lack of consideration of the complexity of mining and geological conditions. Adjusted calculation (Option 3) confirms the economic unreasonableness of its application in the conditions of the "Alardinskaya" mine.

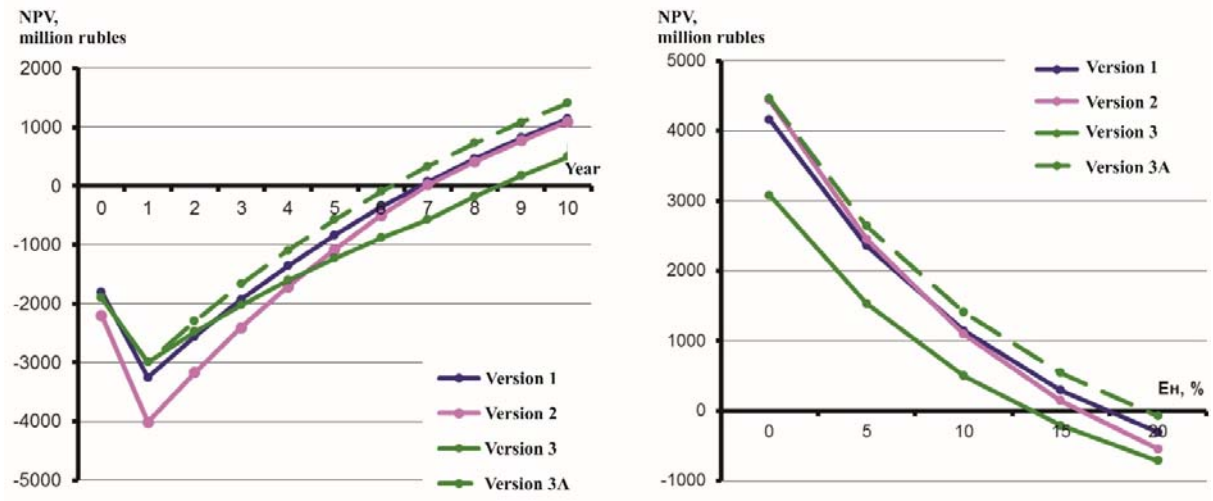

Figure-3. Net discounted revenue for different options of the underground mining development.

Slight in size (within 6%) performance differences between the Options 1 and 2 allow them to be assessed as equally effective. In this situation, the option selection will be determined by the effectiveness of the protective action of the 1 bed mining - as a regional way to ensure the dynamic safety of mining operations at the beds threatened by rock bursts, which significantly changes over time, however, its exact estimation is beyond the scope of this work (Kazanin & Ermakov, *et al*. 2015).

Thus, to ensure stable operation of the mine under these conditions, both the Option 1 and Option 2 may be recommended, because they are characterized by high initial capital costs, and exclude the possibility of a maximum concentration of works according to "mine-

lava" scheme, but ensure a safe and intensive mining of the reserves of the excavation block with high technical and economic performance over the life of the mine.

It should be noted that for the creation of new economically viable mining enterprises the Program provides for the preparation of the relevant coal reserves in areas and fields that are in favorable conditions with regard to consumers and the transport communications, possess high quality coal, and are characterized by high consumer properties (coking coal of most valuable grades, high-calorie energy coal, competitive in foreign markets or suitable for industrial use) (Long-Term Program for the Development of the Russian Coal Industry for the Period until 2030). However, the analysis of the resource base of deposits and their areas shows that the combination of these characteristics is usually very rare. In addition, the availability of high-quality coal is a necessary but insufficient condition for a competitive coal production, even in case of using highly productive mining equipment and modern technologies. For example, the Prokopevsko-Kiselevsky field in Kuzbass has such signs, and is characterized by the highest coal-bearing and coal density rates in the basin, as well as the presence of valuable grades of coal. At the same time, the reserves are deposited in beds assembled in synclinal and anticlinal folds, broken into separate blocks by large geological disturbances (Filatov 2010), which determine their categorization as “extremely unfavorable for mining”, because of the impossibility of effective application of modern high-performance cleaning equipment. In addition, the field development is complicated by the high gas content and a tendency of beds to spontaneous combustion. The mining of the reserves of the Prokopevsko-Kiselevskoye field in Kuzbass now can be characterized by the following facts: the field mines account for 80% of all endogenous fires of the basin, the injury indicators (including lethal injuries) is 5-10 times higher than the average indicators of the underground coal mining in Russia. The impossibility of efficient and safe mining of the reserves of the Prokopevsko-Kiselevskoye field determines the necessity of closing the coal mines, which during the last 20 years has been restrained only by threatening socioeconomic consequences for the region - Prokopyevsk and Kiselevsk are the single-industry cities, since more than 50% of budget revenues is relevant to the proceeds from the underground coal mining.

4. DISCUSSIONS

Under these circumstances, the problem solution is possible only through an integrated approach, implemented both at the design stage and in the operation of mines, providing forecasting and monitoring of geomechanical and aerodynamic situations at all stages of mining.

The complexity of integrating and rational selection of space-planning decisions - opening options, preparation and mining of reserves is conditioned by the following reasons:

- Inconsistency of requirements set by regulatory documents in the mining of reserves in difficult geological conditions (Remezov, *et. al*.2015);
- Impossibility or difficulty of linking of modern rational space-planning solutions and technologies to those previously adopted and implemented in the mines;
- A substantial increase in the complexity of the reserves mining with increasing the mining depth (Catalog of Recommended Ways to Control the Rock Mass Geomechanical State for Russian Coal Mines; Peng 2006);
- Insufficient exploration degree of the effect of undermining and overmining in the mining of adjacent beds.

As an example, we can cite the following series of inconsistencies of requirements set for coal mining technologies in complicated mining and geological conditions:

a) In the mining of beds prone to spontaneous combustion, to ensure reliable isolation of the abandoned sites (exclusion of air leaks, providing the possibility of location and localization of endogenous fires, etc.), the regulatory instrument - “Instruction for the prevention and suppression of endogenous fires at the Kuzbass mines” - provides for leaving the interpillar blocks with a minimum width of 20 m in the mining of beds using long pillars along the strike with the help of mechanized complexes without layering. At the same time, in the mining of the suite of contiguous beds the existence of such blocks leads to the formation of high rock pressure areas, which greatly complicates the works on the overmined bed.

b) The mining of highly gas-bearing beds is characterized by the supply of significant volumes of air to dilute the methane to a safe concentration. However, minimization of pressures and depression in order to eliminate air leaks in the worked-out areas of the mined sites and the formation of the aerodynamic connection during mining of adjacent beds is a necessary requirement to ensure endogenous fire safety when mining the beds prone to spontaneous combustion.

The complexity of linking the modern rational space-planning solutions and technologies to those previously adopted and implemented in the mines is due to a substantial difference in the parameters of technological schemes of coal production, that were previously used and those that are currently in use. Modern high-performance and reliable clearing and excavating equipment can significantly reduce the unit costs of underground coal production by increasing the parameters of extraction pillars. Therefore, for the last 15 years the lava length has increased from 120-200 m (150 m on the average) to 300 m (220 m on the average). The length of extraction pillars has reached, and in some cases exceeded 4 km. At the same time, the parameters of the opening and preparation of mine fields that are used in long-living mines, impose significant limitations on the design and operation of new excavation sites.

For example, the increasing length of the lava in the descending order of mining of adjacent beds prone to spontaneous combustion, leads to undermining of the previously abandoned insulating pillars and edge portions

of the array on the overlying beds, breach of their insulation functions, as well as the formation of high rock pressure areas during cleaning works on the lower beds in the areas of the pillars influence (Kazanin & Ermakov, *et al*. 2015;Yakobi, 1987). In addition, the use of the descending order of mining of the contiguous beds suite lying at minor depths, can lead to the formation of an aerodynamic connection even in the moving of rock beds to the considerable depth, as a result of repeated undermining of the rock array.

5. CONCLUSIONS

The solution of the problem of endogenous fire hazard in the mining of reserves in complex mining and geological conditions can only be achieved through an integrated approach that ensures the consideration of the influence of all geological and mining factors, regulatory documentation requirements (taking into account potential conflicts), current mine and technical situation (in the aspect of space-planning decisions made and planned), as well as taking into account geomechanical and dynamical processes occurring in the bowels (Slastunov, *et al*. 2015). The need to address a significant number of factors, the unicity of their combinations at specific enterprises, combined with the volatility of their influence in the space and often over time, makes this decision extremely difficult and serves as a precondition for a complex of research for each mine and technical situation individually. The absence of a scientific basis during making the space-planning and technical and technological decisions for enterprises engaged in the reserves mining of the beds prone to spontaneous combustion, in difficult mining and geological conditions, involves significant risks of accidents capable of causing significant material damage and even lead to the closure of the coal mining enterprise.

Effective development of the productive capacity of coal companies should be based on the assessment of the resource base, taking into account not only transport accessibility and the value of coal mined, but also the technology of extraction of reserves of the fields and their areas. At the present stage of development of underground coal mining, the use of modern high-performance water treatment systems in long mining faces is characterized by the highest technical and economic performance (Sidorenko & Gerasimova 2016). However, a prerequisite for the successful implementation of the potential of the modern cleaning equipment is, firstly, the existence of favorable mining and geological conditions for its use, and secondly, the use of rational space-planning solutions based on a comprehensive analysis of current and projected changes in mine and technical situation. Less than 1/3 of the mine fields of Russian coal mines are characterized by relatively favorable mining and geological and mining and technical conditions of mining activity. In such conditions, a more effective investment in the mining industry at the moment is really possible only through targeted funding of promising enterprises with significant and effective resource potential. However, in our opinion, taking into account the quality of the resource base of Russian fields, the main direction, ensuring the sustainable and long-term development of the coal enterprises and coal industry of Russia as a whole, should be considered the development and support of technological schemes and rational space-planning solutions allowing to involve in the intensive mining the reserves in difficult geological conditions.

REFERENCES

Catalog of Recommended Ways to Control the Rock Mass Geomechanical State for Russian Coal Mines. 2003. Moscow: National Mining Research Center. A. A. Skochinsky Institute for Mining.

Demin V.F. *et al.*2012. Upravleniegeomekhanicheskimiprotsessamiprivedeniipodzemnykhgornykhrabot [Managing Geomechanical Processes in Underground Mining Operations]. Karaganda: KarGTU Publishing House.

Filatov Yu. M. 2010. O sovershenstvovaniitekhnologiivedeniyaochistnykhrabotnamoshchnykhkrutonaklonnykhplastakhProkop'evsko-KiselevskogorayonaKuzbassa [On Improving of the Extraction Works Technology on Powerful Steeply Inclined Beds of Prokopevsko-Kiselevsky Region of Kuzbass]. Bulletin of the Scientific Center for Safety in Coal Industry. 2: 186-194.

Guidelines for the Rational Layout, Protection and Maintenance of Mining at the Mines of the USSR (4th ed., enlarged). 1986. Leningrad: Ministry of Coal Industry of the USSR; Union Order of the Red Banner of Labour. Scientific Research Institute of Mining Geomechanics and Mine Surveying.

Kazanin O. I. and Zadavin G. D. 2007. Intensivnayaotrabotkavysokogazonosnykhugol'nykhplastovnabol'shikhglubinakh [Intensive Testing of High-Gas-Bearing Coal Beds at Greater Depths]. St. Petersburg: International Academy of Ecology Sciences, Human and Nature Safety (MANEB).

Kazanin O. I., Mustafin M. G., Meshkov A. A., & Sidorenko A.A. 2015. Obosnovanieparametrovtekhnologiiintensivnoyotrabotkipologikhugol'nykhplastov v usloviyakhvrednogovliyaniyagornykhrabotnazemnuyupoverkhnost' [Justification of the Parameters of the Shallow Coal Beds Intensive Development Technology under the Harmful Effects of Mining on the Earth's Surface]. Scientific Bulletin of National Mining University. 2: 51-56.

Kazanin O. I., Ermakov A. Yu., Vanyakin O. V. and Sidorenko A. A. 2015. Issledovanievliyaniyazonpovyshennogogornogodavleniya napokazatelirabotydlinnykhochistnykhzaboevpriotrabotkesvitugol'nykhplastov [Investigation of the Effect of

Increased Rock Pressure Zones on the Performance of the Long Faces upon Development of the Series of Coal Beds]. Mining informational and analytical bulletin. 4: 21-25.

Kuznetsov Yu. N. and Groshenkova O. V. 2003. K voprosupovysheniyakachestvarazrabotkistrategiytekhnologicheskogorazvitiyaugol'nykhshakht [On the Question of Improving the Development Quality of the Coal Mines Technological Development Strategy]. Gornaya promyshlennost. 4: 32-35.

Kushnerov Yu. P., Nifontov A. I., Mikheev O. V. and Tyufyakova O. P. 2005. Ekonomicheskiemetodyupravleniyagorno-podgotovitel'nymirabotamiugol'nykhshakht [Economic Methods of Management of Mining-Preparatory Works on Coal Mines]. Moscow: MAS.

Long-Term Program for the Development of the Russian Coal Industry for the Period until 2030. 2014, April 3. Retrieved October 23, 2016, from http://www.rosugol.ru/programme/index_1.php.

Peng S.S. 2006. Longwall Mining. West Virginia University.

Peng S.S. 2008. Coal Mine Ground Control. West Virginia University.

Remezov A. V. and Klimov V. V. 2015. Issledovanievliyaniyaopornogodavleniyaotochistnogozaboya i zon PGD nagornyevyrabotki, okonturivayushchievyemochnyystolb [Investigation of the Effect of the Reference Pressure from the Working Face and ORP Areas on Mine Openings, Contouring Extraction Pillar]. Ugol', 3: 78-80.

Remezov A. V., Ryabkov N. V., Novoselov S. V., and Kochkin R. O. 2015. Kompleksnyypodkhodpriformirovaniipasportavyemochnykhuchastkov, provedeniya i krepleniyapodzemnykhvyrabotok [An Integrated Approach in the Formation of Excavation Site Passports, Performance and Securing of Underground Workings]. Ugol'. 3: 28-30.

Reshetov S. E. 2006. Printsipyotsenkiurovnyatekhnologichnostideystvuyushchikh i perspektivnykhmestorozhdeniy [Principles of Assessment of the Level of Adaptability of Existing and Prospective Deposits]. Mining informational and analytical bulletin. 12: 102-105.

Shmatko S. I. 2011. On Measures for the Integrated Development of the Russian Federation Coal Industry and Its Legislative Support. Report of the Minister of Energy of the Russian Federation S. I. Shmatko, December 1, 2010. Ugol'. 1, 4-9.

Slastunov S. V., Karkashadze G. G., Ermak G. P and Yutyaev E. P. 2015. Predvaritel'nyy i operativnyyprognozdopustimykhnagruzoknaochistnoyzaboypriintensivnoyotrabotkegazonosnykhugol'nykhplastov [Preliminary and Operational Forecast of Permissible Loads on the Working Face at the Intensive Development of Gas-Bearing Coal Beds].Ugol'. 3: 30-36.

Sidorenko A. A. and Gerasimova I. G. 2016. Determination of Parameters of High Stress Zones at Multiple-Seam Longwall Mining. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 7(3): 1844-1851.

Slastunov S.V., Karkashadze G. G., Ermak G. P, and Yutyaev E. P. 2015. Predvaritel'nyy i operativnyyprognozdopustimykhnagruzoknaochistnoyzaboypriintensivnoyotrabotkegazonosnykhugol'nykhplastov [Preliminary and Operational Forecast of Permissible Loads on the Working Face at the Intensive Development of Gas-Bearing Coal Beds].Ugol'. 3: 30-36.

Sidorenko A. A. and Gerasimova I. G. 2016. Determination of Parameters of High Stress Zones at Multiple-Seam Longwall Mining. Research Journal of Pharmaceutical, Biological and Chemical Sciences. 7(3): 1844-1851.

Strok I.I.and Gorbachev D.K. 1995. TekhnologicheskieaspektyotsenkibalansovykhzapasovuglyaRossiyskoyFederatsii [Technological Aspects of the Assessment of the Balance Reserves of the Russian Federation Coal]. Nauchnye soobshcheniya IGD im. A.A. Skochinskogo. 303: 49-60.

Yakobi O. 1987. Praktikaupravleniyagornymdavleniem [Rock Pressure Control Practice]. Moscow: Nedra.

Zavolokin D. V. 2008. Metodicheskieprintsipyvydeleniyageostrukturuchastkovugol'nykhmestorozhdeniypokriteriyamtekhnologichnost' otrabotkizapasov [Methodical Principles of the Allocation of Geostructures of the Coal Deposit Areas by the Reserves Removal Technological Criteria]. Mining informational and analytical bulletin. 9: 210-213.