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THE INFLUENCE OF COAL MINING LEVEL ON THE DISCHARGE OF EXPLOSIVE GASES TO THE BREAKAGE HEADING

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Abstract

The paper describes the non-linear nature of methane emission into the breakage heading under the influence of geomechanical and gas-dynamic factors. A promising way of reducing the emission of explosive gases by means of intensifying the extraction above a certain critical level and by means of controlling methane emission from broken coal is offered. That will lead to the decrease of methane emission into breakage headings and atmosphere.

Keywords: methane release, hotbed gas, breakage heading

The basic “donors” of gaseous fluids in ventilating flows are breakage headings and working areas of mined-out space. In this case about 85 … 80 % of gases with high content of hydrocarbons, mainly methane come to the mined out areas of Donetsk gassy mines. Nowadays the problems of captation and utilization of methane-air mixtures from the mined-out areas can be solved with the help of decontamination from the surface and underground holes, fume extraction through the pipelines left in waste excavations, and through unsupported excavations. The problem of ventilating streams safety in breakage headings (their expenditure is thousand cubic meters per minute) remains unsolved. A considerable amount of methane, which comes to excavations, is taken out by ventilating streams into atmosphere, and that enhances the greenhouse effect.

Our task is to study the peculiarities of methane release into breakage headings in order to find possible ways of maintaining safe working conditions and to reduce the amount of hotbed gases taken out into atmosphere by ventilating air streams.

Breakage headings in seams l_1 and m_3 of Zasjadko mine are most gaseous in Ukraine. They have been taken as the object of research. The content of gases in coal seams of this mine is about 19 to 23 m^3/t. The total amount of gas in the deposit is about 17,6 billion m^3, in particular in coal seams it is 3,9; in neighboring seams it is 0,8; and in sandstones it is 12,9 billion m^3.

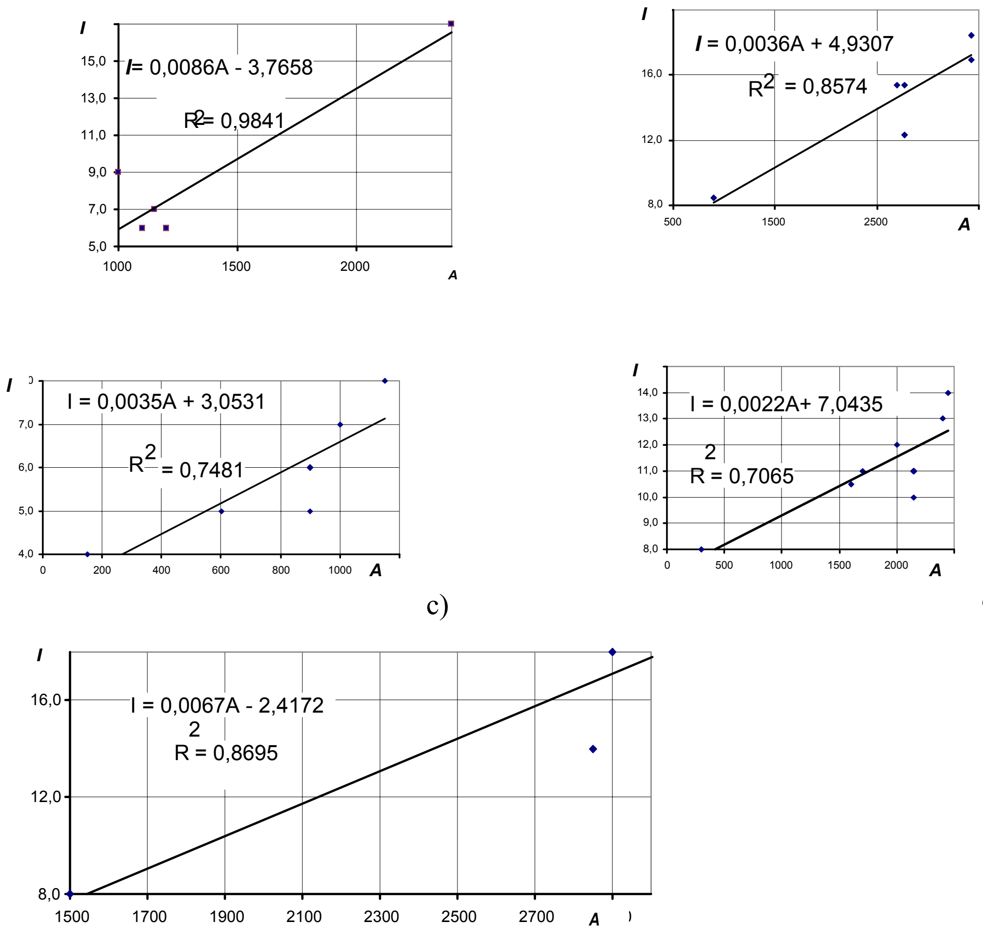
Mining and geological conditions of seams m_3 and l_1 in Zasjadko mine are the following: length of longwall - 240-270 m.; mining system – long-pillar; length of panel – 1700-1900 m; air consumption in a longwall – 1600-2600 m^3/ min. Productivity of longwalls varied from 200 to 5000 tons per day. Mined out area decontamination efficiency was 60 to 90 %; methane emission in a longwall was about 25 m^3/min.

Taking into account the unstable mode of extraction works (due to various technical and organization causes) we analyzed average daily indices of coal production (A, thousand t/day) during one month. It enabled us to obtain reliable results within a rather short period of time. The same approach was used for estimating gas release into breakage headings (I, m^3/min.) and air consumption in ventilating areas (Q, thousand m^3/min.). We used average daily indices of methane content in the longwall “window" during one month.

The estimation of interconnection of loads on the breakage faces with corresponding to them methane emissions into the longwall has led us to the following conclusions.

We have established a reliable connection between productivity and methane emission. Thus the coefficient of connection closeness was 0,67 to 0,98, and for mine observations it is a rather high index. The estimation of statistics of experimental data has confirmed proper quality of the obtained results and that testifies to the high level of experiment methodology.

We have found out that the connection between coalfaces productivity and methane emission is of zonal nature. For a range of daily output less than 2500 … 3500 tons we observed the increase in methane emission with the growth of load on breakage face (fig. 1). The discharge of gas changed from 4 … 8 m^3/ min. (at productivity 200 … 1500 t/day) to 8 … 18 m^3/ min. (at extraction 1200 … 3500 t/day).



a) b) c) d) e)

Figure 1 – Methane emission (***I***, m^3/d) in the breakage headings at productivity less then ***A***= 2500 … 3500, t/d: a) the 9th western longwall of seam $\boldsymbol{l_1}$; b) the 10th western longwall of seam $\boldsymbol{l_1}$; c) the15th western longwall of seam $\boldsymbol{m_3}$; d) the 14th western longwall of seam $\boldsymbol{m_3}$; e) the 12th east longwall of seam $\boldsymbol{l_1}$

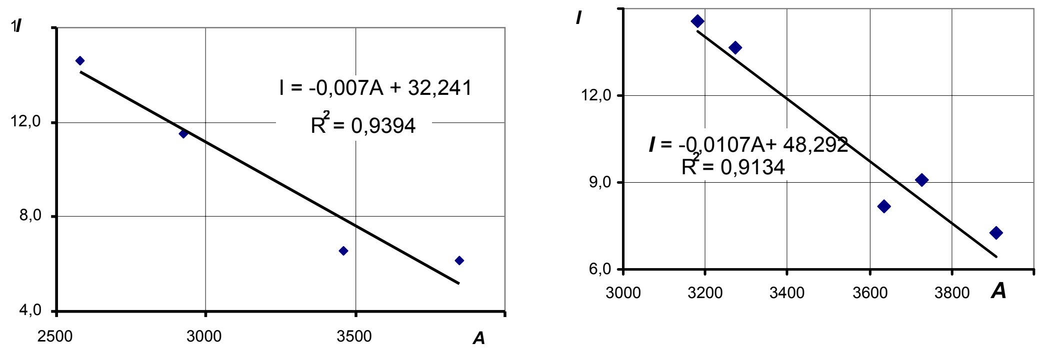
When the extraction was more than 2500 … 3500 tons we observed the decrease of methane emission when the productivity increased (fig. 2). The discharge of gas was decreasing from 15 … 13 m^3/min., when the productivity of longwalls was 2400 … 3000 t/day, to 5 … 7 m^3/ min., when the productivity of longwalls was 2800 … 4000 t/day. Reduction of methane emission in breakage heading reached 50 % and more.

In case when breakage face productivity varied within the range which included a zone of low productivity (to 3500 t/day) and a zone of high productivity, the statistics trend was represented by a parabola (fig. 3, a). In this case the extremum was in the range of productivity 3100 … 3200 t/day, and the maximum of methane emission reached 22 … 25 m^3/min.

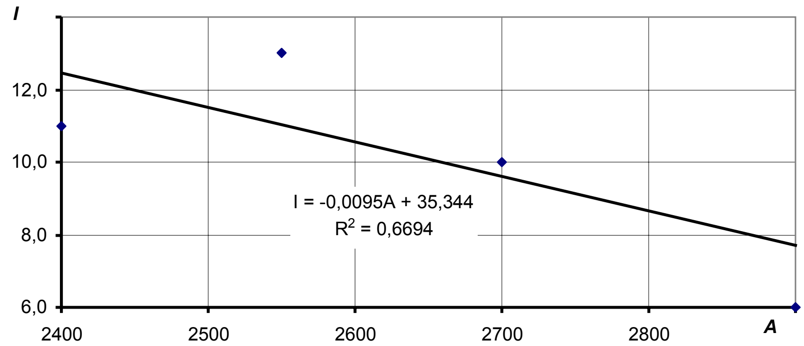
Having summarized the obtained results we can suppose that for particular mining and geological conditions of coal seams extraction there is a certain regularity of methane emission into a breakage heading.

It consists in the following: if the intensity of coal extraction is low the increase of the load on the breakage face leads to the growth of gas emissions into longwalls. Further increase of the breakage face productivity is accompanied by the decrease of methane emission into a longwall.

This statement is confirmed by the data of Moscow National University of Mines [2]. This data are related to methane emission in breakage heading of Russian mine "Kotinsky" of Public Corporation "SUEK-KUZBASS" where a thick coal seam was mined (fig. 3, b). The best indices for the given statistics had a trend in the form of a downward parabola.



a)



c)

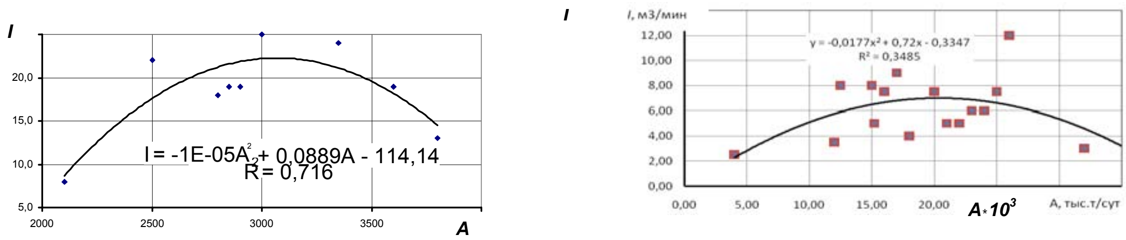
Figure 2 – Methane emission (***I***, m^3/d) in the breakage headings of seam l_1 at productivity of longwalls more then ***A***=2400 … 3500, t/d: the 10th western; the 11th east; the10th east

Similar mechanism of methane emission into a breakage heading can be explained in the following way. Free methane comes from the seam, roof and bottom rocks, broken coal and mined out space to the excavation cavity.

Gas in the rock mass from the bound state passes into the free state. It occurs under any type of deformations: tension, compression, bend, torsion, etc. [3]. It is known from geomechanics that the prevailing number of deformations of sedimentary rocks near the excavation contour is realized in the form of cracks. The main stimulus of gases migration in coal substance is the diffusion caused by the difference of concentrations or pressures. The intensity of the process of gas liberation from coal monoblocks is determined by their sizes. Destruction of a coal seam at deep levels (where coal is in extreme stress state) begins on the boundary of the area of the influence of a breakage heading on the surrounding rock mass. However, due to low porosity high pressure of free gas is realized in the cavities and diffusion slows down.

Diffusive process becomes more intensive only under the decrease of pressure due to unloading of rock mass with the increase of porosity or when gas goes to excavations. Therefore the increase of the rate of the movement of a longwall above some particular level reduces the volumes of gas released as a result of diffusion and methane content of critical area of formation grows.

Gas drainage from critical area of formation and rocks occurs in the form of filtration on cracks. The amount of gas emitted in the excavation is determined by: the size of fractured zones; the fracture direction in this zone; the filtration coefficient which shows at which distance for a unit of time a fluid penetrates; a gradient of gas pressure between the area boundary and excavation surface.



a) b)

Figure 3 – Connection between methane release (***I***, m^3/d) and productivity (***A***, t/d): a) the 9th western longwall of seam l_1; b) longwall №5203 of "Kotinsky" mine

With distance from the excavation contour the number and width of cracks of rock pressure gradually decrease to the background state typical of virgin rock mass. The porosity of environment is determined by the number and width of cracks. In the parts of a seam where their width is small and their number is great, for example, in a zone of abutment pressure, effusive processes are of certain importance [4] and that determines the delay in gases migration.

The deformations in sedimentary rock and coal environment surrounding excavation are realized in space and time. That is, it is possible to single out a rock deformation component, which is independent from the time of excavation existence, and a chronological component of the deformations. The slower the breakage face advances the greater is the share of the second component of deformations. The virgin rock mass boundary (background state) gradually moves away from the stable contour of excavation. This fact is confirmed by continuous displacements of the excavation rock contour.

It is experimentally proved that the value of deformations on the excavation contour (in particular roof and bottom convergence in the longwall) depends on the rate of breakage face advancement. The greater is the rate, the smaller is convergence; it can be explained by insignificant value of the chronological component of deformations. Besides, qualitative features of fissuring formation are known, they consist in the prevailing development of interlayer cracks when the rate of breakage face advancement is increased [5]. In these conditions the cracks oriented normal to bedding have no time to form. Thus, with the increase of the rate above a certain level determined by strength properties of coal and rock mass, the number of cracks in a seam and surrounding strata decreases and their anisotropy grows. Consequently we should expect the reduction of methane emission into a breakage heading (when the rate of breakage face advancement is high) due to the decrease of the sizes of the gas drainage zone and worsening of filtration conditions in it.

It is important to consider the fact that the intensity of methane emission in the breakage face is determined not only by geomechanical processes in surrounding rock mass, but also by gas-dynamic processes. Such indexes as methane content in seams and rocks, the value of gas pressure in them, the temperature (dynamic viscosity) of gas, etc. also determine the level of gas coming to a longwall.

One more source of methane release into a breakage face is the coal broken by a combine. The gas contained in the pore space is liberated due to the destruction of coal structure by a combine. Gases desorption from fresh coal surfaces takes place and their diffusion goes on in the pieces separated from a seam.

The researches carried out at Donetsk National Technical University [6] showed that the fractional composition of the broken coal depends on the advance speed of a combine along a face. For example, with the increase of the speed of a combine 2K-52 from one to six meters per minute the content of small fractions (less than 6 mm) decreases from 46 to 24 % and the content of large fractions grows from 3 to 15 % (fig. 4). Such dynamics of coal grade reduces methane emission from broken coal into a breakage heading in case of intensification of coal extraction.

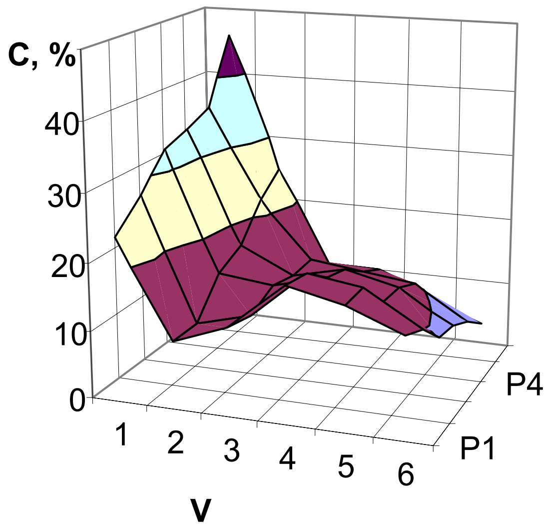


Figure 4 – Change of fractional composition (C, %) of the broken coal in case of the change of the advance speed (V, m/minute) of a combine along a face: P_1-P_6 – the size of fraction, P_1 - more than 100; P_2 - 50 … 100; P_3 – 25 … 50; P_4 – 13 … 25; P_5 – 6 … 12; P_6 – less than 6 millimeters

Similar mechanism of methane emission into a breakage heading can be explained in the following way. Free methane comes from the seam, roof and bottom rocks, broken coal and mined out space to the excavation cavity.

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With the increase of the size of a coal piece the diffusive liberation of gas decreases according to hyperbolic law. Consequently, with the improvement of the broken coal grade the release of methane from the rock mass transported along the longwall slows down considerably. The further prevention of methane coming to the excavations from the supplied rock mass can be provided by using tubular conveyors or by solitary ventilation of conveyor excavations.

In general the process of methane release into the breakage heading is as follows. When the loadings on the breakage face are small the growth of productivity is accompanied by the increase of methane release into a longwall. The maximum allocation of methane is observed when a certain relatively high rate of seam mining is reached. During this period there is a dynamic balance between the amount of gas, which comes into the excavation, and the amount of gas, which remains in the broken coal taken out beyond the limits of a fresh air-stream. Further increase of face advancement rate leads to the reduction of the sizes of methane drainage area and to the increase of fractional characteristics of the broken coal. After that methane release into the breakage heading decreases.

Additional reduction of methane release into the breakage heading can be explained by the improvement of the grade of quality of broken coal and the increase of loading on the breakage face. It leads to the increase of advance speed of a combine. In this case the duration of gas diffusion from coal pieces increases according to hyperbolic dependence.

Another source of methane release into the breakage heading is mass transfer between the heading and the mined-out space. The basic type of mass exchange is turbulent diffusion. It depends on the speed of air-gas stream movement in a longwall and nearest part of the mined-out space, methane concentration, density of the wall dividing the breakage heading and the mined out space, etc. The roof support of type KD was used while mining the layers l_1 and m_3 at Zasyadko mine, that determined the homogeneous character of the influence of dividing wall. The speed of streams movement depended on the parameters of aerodynamic resistance of the excavation, the open area and local depression. A reliable correlation between methane emission in the breakage heading and air consumption was not confirmed.

Air-gas surveys [7] carried out by the staff of the ventilating service of the mine and the specialists of Dnepropetrovsk Institute of Geotechnical Mechanics have shown that at direct-flow ventilation no more than 7% of methane-air mixture come to the breakage heading from the mined out space. It contradicts the existing opinion about the direct release of considerable amounts of methane into the breakage heading from the open area [5].

The greatest interaction of aerodynamic streams of the longwall and the open area is observed in case of return ventilation on the coal mass. However in the majority of cases there is a technical possibility of controlling the correlation between air streams in a breakage face and adjacent mined-out space using ventilation and geomechanical means. There is also a possibility of reducing methane release into the longwall.

On the basis of the obtained data it is possible to change the balance of gas streams in the excavations by means of reducing methane emission in the longwall Q_{oz}, (fig. 5). Besides, we offer to reduce uncontrollable emission from the broken coal in a longwall and the conveyorway Q_{ct}, Q_r. For example, the broken coal can be covered with a foam coating and placed in the tubular conveyor. Decontamination of surge bin Q_d is especially effective for this purpose. In Donetsk National Technical University we began a research and obtained preliminary positive results as for the intensification of gas release from transported coal using microwave electromagnetic radiation. It allows lowering a share of methane X_o taken out from mine.

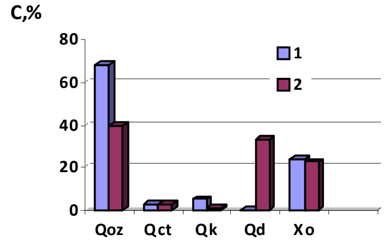

Figure 5 – Balance of methane emission from a seam with the natural gas-abundance: 1. 2 – the methane streams at existing (1) and offered (2) parameters of breaking and transportation of coal; Q_{oz}, Q_{ct}, Q_r, Q_d, X_o - methane expenditure (released from the seam; from the broken coal in a longwall; the same on the conveyorway; arriving in decontamination system; remaining in coal)

Conclusions

1. Experimentally on the basis of mine observations we established a nonlinear dependence between the loading on the breakage face (***A***) and methane release into the breakage heading (***I***) in the conditions of seams l_1 and m_3 of Zasyadko mine. We observed the increase of methane release from ***I***=4 … 8 to 11 … 20m^3/min at productivity in the range of 500<***A***>2500 t/day. The further growth of the productivity of a longwall to 3500 t/day and more led to the reduction of ***I*** to 5 … 15m^3/min.

2. Data handling confirmed sufficient quality of the obtained statistics. The closeness of the connection between the loading on a breakage face and methane release into a breakage heading was characterized by factor $\boldsymbol{R^2 \geq 0,7}$.

3. The established laws were confirmed by experimental data obtained by Moscow National Mining University at "Kotinsky" mine when mining a thick coal layer where methane emission into the breakage heading is also described by a downward parabola. It allows making a hypothesis about similar nature of methane release in other coal-fields.

4. Nonlinear nature of methane emission in breakage headings can be explained by joint influence of geomechanical and gas-dynamic factors. At low rates of face advancement there are favorable conditions for formation of the filtering environment in the rock mass surrounding the longwall and for gases escape into the breakage heading. The size of drainage area is maximum, the number of cracks and their opening is maximum. They are oriented both parallel and normal to the bedding plane. A considerable amount of free methane comes from the coal seam, roof and bottom rocks into the excavation cavity. In these conditions the increase in the rate of coal extraction determines the growth of methane emission into a breakage heading. Such dynamics can exist up to a certain level depending on the correlation of real mining, geological and organizational conditions of mining works. After achieving a certain rate of seam extraction we can observe maximum methane emission. Further increase of the rate of a breakage face advancement leads to the reduction of the sizes of methane drainage area. Besides, the cracks of pressure become oriented mainly along the bedding and that leads to methane release into the mined-out space. As a result, when the rate of the face advancement exceeds the maximum, methane emission into the breakage heading decreases.

5. Additional reduction of methane release into the breakage heading can be explained by the improvement of the grade of quality of broken coal and the increase of loading on the breakage face. It leads to the increase of advance speed of a combine. In this case the duration of gas diffusion from coal pieces increases according to hyperbolic dependence.

6. The researches have allowed offering a promising way of reducing the emission of explosive gases by means of intensifying the extraction above a certain critical level and by means of controlling methane emission from broken coal. That will lead to the decrease of methane emission into breakage headings and atmosphere by 50 % and more.

References:

1. Руководство по проектированию вентиляции угольных шахт: ДНАОТ 1.1.30-6.09.93. – Офиц. издан. – К.: «Основа» 1994. – 312 с. (Нормативный документ Минуглепрома Украины. Руководство).
2. Лупий М.Г. Обоснование технологии комплексной дегазации выемочных участков при высокоинтенсивной разработке газоносных угольных пластов: автореф. дис. на соискание науч. степени канд. техн. наук: спец. 05.26.03 «Пожарная и промышленная безопасность» / М.Г. Лупий; Московский гос. горн. ун-т. – Москва, 2010. – 21 с.
3. Костенко В.К. Уточнение параметров попутной дегазации угольных пластов / В.К. Костенко, А.Б. Бокий, Е.В. Шевченко // Метан: Сб.науч.тр. по матер. симпоз. «Неделя горняка - 2008». Отд.вып. Горного информ.-аналит. бюлл. – М: «Мир горной книги», 2008. – С. 239-247.
4. Костенко В.К. Изменение физических свойств углегазового массива под влиянием очистных работ / В.К. Костенко, А.Б. Бокий // Геотехнічна механіка: Міжвід. зб. наук. праць. Дніпропетровськ: Ін-т Геотехнічної механіки ім. М.С. Полякова НАН України. – 2008. – Вип. 80. – С. 90-97
5. Назімко І.В. Обґрунтування параметрів інтенсивної технології виїмки вугільних пластів на великої глибіні: автореф. дис. на здобуття наук. ступеня .канд. техн. наук: спец. 05.15.02 «Підземна розробка родовищ корисних копалин» / І.В. Назімко; Нац. гирнич. ун-т. – Дніпропетровськ, 2009. -18 с.
6. Афендіков М.Г. Вибір раціональних параметрів очисних комбайнів зі шнековими виконавчими органами для роботи у складних умовах по зарубаемості: автореф. дис. на здобуття наук. ступеня канд. техн. наук: спец. 05.05.06 «Гірничі машини» / М.Г.Афендіков; Донецьк. політех. ін-т. – Донецк, 1980. – 202 с.
7. Проветривание и газовый режим шахты имени А.Ф. Засядько: состояние и пути совершенствования / Е.Л.Звягильский, А.Ф.Булат, И.А.Ефремов. и др. – Донецк–Днепропетровск: ИГТМ, 2003. – 228с.

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