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UPDATE ON THE STATUS AND ACTIVITIES OF THE TASK FORCE ON THE ECONOMIC BENEFITS OF IMPROVING MINE SAFETY THROUGH THE EXTRACTION AND USE OF COAL MINE METHANE

Conceptual approaches to the development and working of very gassy coal deposits

Papers submitted by the expert from the Russian Federation

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I. AN INTEGRATED APPROACH TO DECISION-MAKING REGARDING MINING PROJECTS

2. In fixing a strategy for the intensive development of very gassy coal deposits, it is important to follow an integrated engineering and economic approach that will enable management to view all the problems as a whole rather than, as is usually the case at present, as discrete, poorly connected sets of issues.

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3. Given the particular deposit conditions and structure of the gas balance at mines in the Vorkuta region (the gas balance is distinguished by a high proportion of spent workings in both active and abandoned mining areas), gas is the decisive factor in the overall system of mining economics and safety. The deposits therefore have to be treated as methane-and-coal deposits.

II. THE CONCEPT OF WORKING A COAL DEPOSIT AS A METHANE-AND-COAL DEPOSIT

4. The extraction of coal methane and the mining of coal are closely interlinked: intensive extraction of methane from coal seams in active coalfields leads to significant improvements in the productivity and profitability of coal mining and at the same time yields gas for use in industry. In the final analysis, that increases coal's share of the national energy balance. Looking at it from another point of view, coal mining destresses the rock mass and increases methane emission from coal-bearing gas-saturated rock. However, to ensure stable methane flows (in terms of volume and concentration), account must be taken of the laws governing methane emission from coal in stressed strata (methane extraction prior to the commencement of mining) and destressed strata and from old workings in active and decommissioned mines, as well as of the effect of air filtration processes in the gob on the parameters of the recoverable gas/air mixture.

5. Use of the laws of methane emission from coal-bearing rock and the development of technology for improving the efficiency of methane extraction at the various stages of mining (before development, during coal-getting and after mine closure) will help to ensure the optimum combination of coal-winning and gas-extraction from coal deposits.

6. The principle behind the methane-and-coal concept for the working of very gassy coal deposits is that of conducting coal methane extraction at all stages of mining activity, due allowance being made for mining-related changes in the filtration properties of the gassy coal-bearing strata.

7. Successful application of the concept requires: sufficiently reliable forecasts of the methane reserves in mining areas during the planning, construction and operation of mines and after they have closed; and the use to extract the gas of technology suited to the mine geology in each particular case.

8. Gas extraction should begin early, 5-10 years before development of the mine starts. Account must be taken in deciding on the well pattern and siting parameters of the plans for the coal mining that will come later: the more the seams to be worked can be degassed, the lower will be the risk of methane explosions during coal-getting.

9. The methods developed by MSMU for increasing coal-seam gas permeability by means of hydrofracturing wells ensure a high degree of degassing (rising over time from the beginning of gas extraction to the beginning of coal-winning) at well flows of the order of 1-2 m^3/min. For example, in the space of eight years 14 wells using MSMU technology have produced more than 18 million m^3 of virtually 100% methane from the thick, explosion-prone D_6 seam at the Lenin

mine in the Karaganda coal basin. Much the same performance has been achieved using similar technology in the United States of America (except in the San Juan basin, where a micro-deposit of natural gas was discovered).

10. Coal-getting during the active life of a mine relieves stress in the rock mass and increases methane emission from the coal-bearing gas-saturated strata. Methane extraction during this period is best effected by combining the use of wells sunk from the surface for methane drainage before mining begins with that of underground boreholes. Destressing the rock mass greatly increases well flow, but also increases the amount of air extracted from workings and reduces the gas concentration, requiring special measures to maintain the conditioning parameters of the gas/air mixture. For example, underground degassing in the Pechora basin yields some 300 million m^3/yr and the concentration of gas in the extracted mixture ranges from 7-12 to 35-40%. Up to 80% of the gas comes from spent workings that constitute natural methane-filled reservoirs and emission from them continues for several years after mining ends.

11. To ensure methane flows that are stable in terms of volume and concentration, account must be taken of the laws governing methane emission from destressed strata and old workings and of the effect of air filtration processes in the mined strata on the parameters of the recoverable gas/air mixture.

12. When mines are closed down, considerable quantities of methane remain in the spent workings (estimates put the amount at two to three times the volume of gas emitted during coal-winning). Russia has no experience of extracting methane from worked-out areas, but results from other countries show that it is economically very worthwhile:

(a) In 25 years, 365 million m^3 of gas (average flow rate 33.5 m^3/min) containing 50-60% methane and 3% ethane and worth over $40 million was recovered from Australia's Belmain pit, which was closed in 1942 after an explosion;

(b) 265 million m^3 (average flow rate 20.2 m^3/min) worth $29.15 million were recovered from the Santa Barbara mine in the Saar (Germany) between 1959, when the mine was closed, and 1985;

(c) In France (Nord-Pas de Calais), work on extracting methane from abandoned mines began at the end of the 1970s. The amount captured between 1982 and 1984, a period of approximately three years, was 9 million m^3 (average flow rate 6.5 m^3/min; methane concentration as high as 70%). In 1985 alone, methane capture totalled 55 million m^3 (average flow rate 104.6 m^3/min) and was worth $6.05 million.

13. It can be seen then that changes in the laws of methane desorption and drainage during the various stages of exploitation of a coal deposit also require changes in the technology for extracting gas. As a result, we can distinguish three stages of methane extraction, corresponding to fundamentally distinct stress-strain states of the ground:

(a) The *period of mine design and construction*, which corresponds to the period of methane extraction from rock that has not been destressed by mining activities;

(b) The *period of operation of the mine* until reserves are fully depleted or the mine is closed for other reasons (development, extraction of the planned quantity of coal, abandonment), which corresponds to the period of methane extraction from destressed rock;

(c) The period from commencement of the sealing-off of individual areas and of *closure of the mine* as a whole to the complete exhaustion of the gas in the worked strata. This period corresponds to the period of extraction of methane from spent workings.

14. As these three phases are not clearly separate in time, i.e. stress conditions in the rock mass alter constantly during mining (from the natural state until the completion of full displacements), they may all exist simultaneously at one and the same mine. The most sensible option, therefore, is to use a multistage technology, one in which the same wells are used for methane drainage at all stages of working of the deposit. The wells will, however, be operated differently as working progresses from its first to its final stage.

15. The main requirements that degassing wells must meet during the period of operation of the mine (degassing of rock destressed by mining activities) can be summed up as follows:

(a) Prevention of methane explosions by reducing the methane content of workings by the requisite amount and keeping the mine atmosphere gas-free. This significantly improves the productivity of mining;

(b) Maintenance of conditioned flows of the gas/air mixture thanks to: the creation of a system for monitoring and controlling methane flow and concentration in the piping network; the presence of a system for preparing the extracted gas/air mixture for delivery to the client; the minimization of the length of the piping network so as to reduce the risk of leaks and keep down the amount of air drawn into the system (reduction of methane dilution); the aerodynamic control of methane distribution in mined areas; reliable isolation of worked-out areas from active workings, etc. (the quality requirements applicable to the extracted gas/air mixtures depend on how the methane is to be used and vary widely in terms both of flow rate (1.5-15 m^3/min or more) and of concentration (0.5-80% or more);

(c) Through the optimum choice of equipment parameters in the light of the laws governing the flow of methane into the wells, recovery of the cost of extracting and marketing the methane;

(d) Safe operation in terms both of the stable, accident-free functioning of the entire gas drainage system and of compliance with health and environmental standards.

Adopting this multistage approach to methane extraction during working of a deposit not only enables fuller use of the deposit's natural resources but also enhances the efficiency of coal-winning, since the reduction of methane emission into the mine atmosphere improves staff's safety and productivity and cuts operating costs.

16. If the three-stage approach to methane extraction is adopted, the most sensible course is to use a combination of wells oriented in differing directions: for contiguous seams at working depths up to 400-450 m, wells sunk from the surface, and at greater depths, underground boreholes from supported roadways in the adjacent seams; for worked-out areas at depths up to 400-450 m, wells sunk from the surface, and at greater depths, underground boreholes from (ventilation, drainage, etc.) roadways in contact with the area in question, together with optimized air-flow conditions.

17. The table below shows the main indicators for methane emission from destressed ground by source of emission.

	Methane source (zone to be degassed)			
	Active seams	Contiguous seams (caving)	Gob	Combined
Average methane flow, m^3/min	Up to 3.0	16-20	10-17	-
Methane concentration at well mouth, %	95-100	80-90	10-80*	-
Methane concentration at vacuum pump station, %	35-45	35-40	8-70*	25-40
Range radius of well, m	10-15	From 20-25 to 140-260*	80-120	-
Efficiency of degassing, %	15-30	35-40	35-16 (up to 95*)	60-90

* Assuming degassing by surface wells.

18. The efficiency of methane extraction in areas of active mining depends heavily on the coal-winning technology and the quality of the degassing efforts, i.e. the proper application of the degassing technology. When it is properly done, extracting coal-mine methane costs no more than extracting natural gas (an average of approximately $8.8 per 1,000 m^3).

III. AN EXAMPLE OF PRE-MINE DRAINAGE (PMD) AND ACTIVE DRAINAGE (AD) OF METHANE FROM UNRELAXED COAL-BEARING ROCK VIA WELLS SUNK FROM THE SURFACE AT THE LENIN MINE IN THE KARAGANDA COAL BASIN

19. PMD is based on the advance extraction of methane from coal mines by means of wells drilled from the surface. The extraction is preceded by artificial enhancement of the permeability of the coal seams by various kinds of pneumatic, hydraulic, physicochemical and other treatment of the coal- and gas-bearing strata.

20. Since 1962, various versions of the PMD technology developed by MSMU have been applied at more than 20 underground mines in the Karaganda and Donetsk coal basins.

21. The effects of PMD by means of hydrofracturing have been shown to last for from 3 to 12 years with the extraction of up to 5 million m^3 of 95-100% methane from a single well, not counting the additional methane production consequent on destressing of the rock mass during mining.

22. PMD can reduce the gas content of mine workings by 75-80%.

23. The main features of the PMD technology are protected by a total of more than 90 copyright certificates and patents.

24. MSMU holds patents protecting all the main PMD procedures and operations within the Russian Federation.

25. MSMU is the author of the main normative documents pertaining to PMD, including manuals and technical specifications.

26. Experience in applying more than 20 degassing techniques in the Karaganda coal basin has shown that degassing of the coal seam itself is an essential stage of overall degassing for faces with an output in excess of 5,000 t/d. Underground seam degassing is very inefficient in very deep workings with low permeability (conditions that are especially common in the Vorkuta deposit). That is because of the lack of time for methane drainage and the impossibility of boosting permeability by acting on the rock in the vicinity of workings. The only option in such circumstances is PMD via wells sunk from the surface.

27. There follows a description of the main technical aspects of PMD.

28. Coal seams are degassed by hydrofracturing when they have a natural gas content of more than 10 m^3/t and lie in water-saturated rock of no less than average strength.

29. Pre-mine drainage is carried out for a period of more than three years (preferably five to seven years) and active degassing, (either alone or in combination with in-seam boreholes) for up to three years.

30. Degassing comprises three main stages: 1, hydrofracturing; 2, well completion (removal of drilling mud from the seam by means of pumps or in-seam wells, gas extraction); 3, pumping of gas from the gob after caving around the well as mining progresses (fig. 1).

31. Pre-mine drainage wells are sunk not less than 300 m from active workings along the line of the main system of natural coal-seam fractures and at not more than their range radius from dislocations of an amplitude exceeding the thickness of the worked seam.

IV. ASSESSMENT OF THE EFFICIENCY OF PRE-MINE DRAINAGE AT THE LENIN MINE

32. Recent work at the Lenin Mine in the Karaganda coal basin has given solid proof of the economic benefits of pre-mine drainage. Surface wells have been in operation at the mine for more than eight years and are currently still extracting methane from the thick, explosion-prone D_6 seam. Over the space of eight years, the 14 wells have produced 18 million m^3 of 100% methane, reducing the gas content of the seam to 6-9 m^3/t. The current flow from the series of wells is in excess of 1-2 m^3/min.

33. The economic benefits include:

(a) Reduction by 1,500 m of the sinking of paired winzes on the left wing of seam D_6 (only 50% of the reserves in which are worked by hydrofracturing), saving 24 billion roubles;

(b) Increase in coal yield from the hydrofractured zones. Using the current methods, extraction of 1 million m^3 of methane increases coal yield by 22,500 t. Consequently, PMD of 20 million m^3 of methane increases coal yield by 450,000 t, which, even allowing 25% for the cost of degassing, represents a saving of 18 billion roubles;

(c) For the past few years, some of the methane from hydrofracturing wells has been used to heat a new hoisting shaft. In three heating seasons, this has consumed 1,600 m^3 of gas, saving 3,000 t of coal worth more than 4 million roubles.

34. The combined savings under these three headings alone amount to 46 million roubles. At a cost for the 14 hydrofracturing wells of 6 million roubles in current prices, the saving from pre-mine drainage of methane at the Lenin Mine is 40 million roubles.

35. To the benefits already mentioned must be added the improvement of safety in hydrofracturing zones. Not only is the gas content of workings lower, the risk of explosions is much reduced too. During the workings of seam D_6 there has been a total of 106 recorded incidents of coal/rock and gas bursts of varying intensity. Virtually all of them, including the most recent one, which killed three miners, have occurred outside the zones of influence of the hydrofracturing wells.

36. The environmental effects of the work have also been extremely positive. The benchmark facility set up at the mine currently recycles 20 m^3/min of methane and it is planned to increase this figure in the very near future to 60 m^3/min, of which 40 m^3/min will be methane extracted via hydrofracturing wells. Recycling 510 m^3 of methane saves 1 t of steam coal and cuts harmful emissions to the atmosphere by 55 kg.

37. Based on these reliably representative proofs of the benefits of pre-mine drainage via surface wells, the Coal Department of ISPAKARMET, a joint-stock company set up on the basis of the Karagandaugol Production Association, has adopted a development programme for the drilling over the next seven years of a further 150 wells in the Karaganda basin.

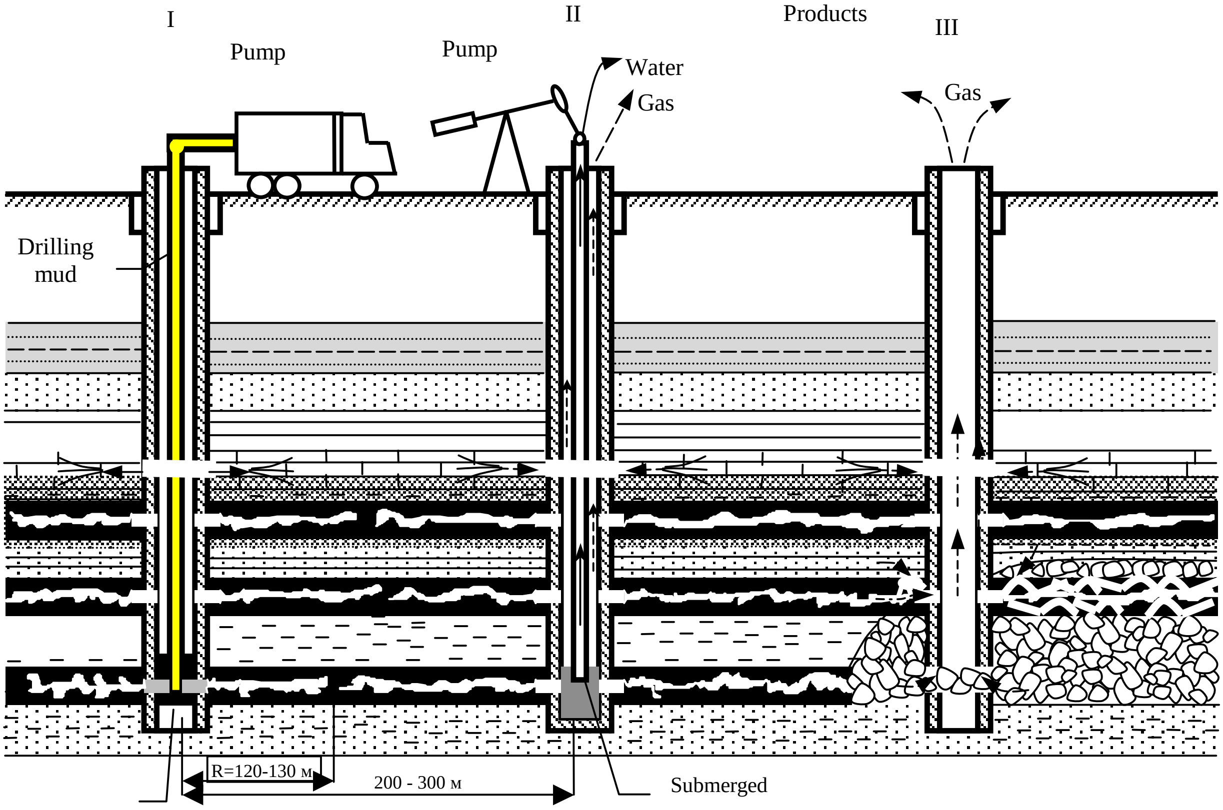

Figure 1. Multi-stage method for degassing of a suite of coal seams via surface wells

I. Hydrofracturing and other treatment of unrelaxed suite of seams

II. Well completion (extraction of water and methane)

III. Degassing of gob
