Forecast and Prevention of Coal and Gas Outbursts in the Case of Application of a New Mining Method - Drilling of a Coal Pillar

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Coal and gas outbursts are one of risk factors accompanying the mining of coal in low seams in the Ostrava-Karviná Coalfield. At the use of the method of longwall mining, all coal reserves have not been mined out owing to tectonic faults. For mining out the residual reserves, the application of a new mining method - drilling of a coal pillar was proposed.

The method of mining of a coal seam utilizing long large diameter boreholes is verified in the Paskov Mine (company OKD, JSC – Czech Republic) under conditions of rock mass with hazard of rock and gas outbursts in localities of residual pillars left in seams after finishing the mining operations performed with using the classical method of longwall working along the strike. [5]

Forecast and preventive measures applied to the verification of the new method were based on previous experience with the mining of seams with hazard of coal and gas outbursts. They accepted fully valid legislation, i.e. Ordinance of Ostrava Regional Mining Authority No. 3895/2002 and supplementary materials (Instructions and Guidelines). The proposed measures respected the character of the method being verified. [4]

For all areas being mined, projects containing also chapters specifying the problems of ensuring the safety of mining works and operation under conditions of hazard of coal and gas outbursts were prepared.

In the contributions, basic proposals for the principles of coal and gas outburst forecast and prevention when applying the new mining method – drilling of a coal pillar are presented.

Key words: *coal and gas forecast and prevention, mining method, large diameter boreholes, mining system*

Introduction

The aim of the contribution was to make the reader acquainted with a proposal for the procedure of rock and gas outburst forecast and prevention in the case of a new mining method based on a variant of "drilling-auger system" [3] – a modified machine VS-SEAL-625 P1 (P2) from the company SE-MI Service – under conditions of the Paskov Mine (Czech Republic, OKD) according to [1].

Methods of Forecast When Mining under Conditions of Hazard of Coal and Gas Outbursts

In the course of mining with using the method of longwall working along the strike, the forecast is always carried out and evaluated in accordance with Article 7 of Ordinance of Ostrava Regional Mining Authority No. 3895/2002 (henceforth referred to as Ordinance) and in connection with it in accordance with Articles 3 to 7 of Annex to this Ordinance (INSTRUCTIONS for Mines with Hazard of Rock and Gas Outbursts), and according to valid methodological procedures [2].

In the case of new mining method, the implementation of the forecast must be modified to suit the method being verified that does not correspond to the conditions for which the Ordinance was approved; simultaneously, the principles determined by valid legislation must be kept.

The forecast in the course of mining of coal by means of large diameter boreholes, i.e. a new mining method not verified yet, must be carried out during the trial operation performed in the framework of research and development as "other method of forecast" in the sense of Article 7, Clause (5) of Ordinance, where it is stated that:

> *"Forecast measurements of rock and gas outburst hazard must be carried out by methods stated in Instructions. The application of other methods being developed or verified in the framework of research and development even in case of possible omitting the methods approved is permissible only with the approval of the mine manager…".*

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From the above-presented citation it is obvious that for the method not verified yet, "other method of forecast", namely local or continuous, may be used. In practice, this means that it was necessary to modify the existing methods and to adapt them to new conditions.

Local Forecast

Generally, the local forecast must be implemented in sufficient advance of the commencement of mining operations and must include the following items:

1. Evaluation of available geological data.
2. Evaluation of local forecast carried out earlier in the seam in the given locality.
3. Evaluation of continuous forecast implemented earlier in the course of driving a working from which mining operations by drilling will be performed.
4. Verification of geological structure and gas properties of seam of the block planned for working by special long forecast boreholes implemented according to valid legislation.

For the proper implementation of local forecast in the locality, if any local forecast has not been performed here in advance, we propose to execute obligatorily the following procedure:

1. Before the commencement of mining operations themselves, to drill special long forecast boreholes (SLFB) in the seam in a part of block of interest.
2. To drill SLFB in sufficient advance of the implementation of outburst prevention and of the subsequent commencement of mining operations.
3. SLFB will be drilled from the haulage entry perpendicularly to the pillar; they will exceed the block planned for mining out at least by 10 meters on both the sides.
4. The length of SLFB, the method of measurement of forecast indicators and the method of their evaluation will comply with the Instructions for Mines with Hazard of Rock and Gas Hazard) (henceforth referred to as Instructions) and with the Working Rules to the Instructions.
5. Forecast indicators will be determined in the extent of the following table and will be evaluated according to criteria stated in Instructions.

Indicator - name	Indicator - symbol	Measured units
Desorbable gas content	Q_{RH}	$m^3.t^{-1}$
Initial desorption rate	V_1	$cm^3.(10g.35s)^{-1}$
Initial gas production rate	q_p	$1.min^{-1}$
Gas pressure	p	kPa

The local forecast performed like that will replace the local forecast in the course of implementation of long mine workings in the phase of development of logwall face, according to the results of which the face must be classified.

A forecast borehole pattern is clear from the following figure, Figure 1.

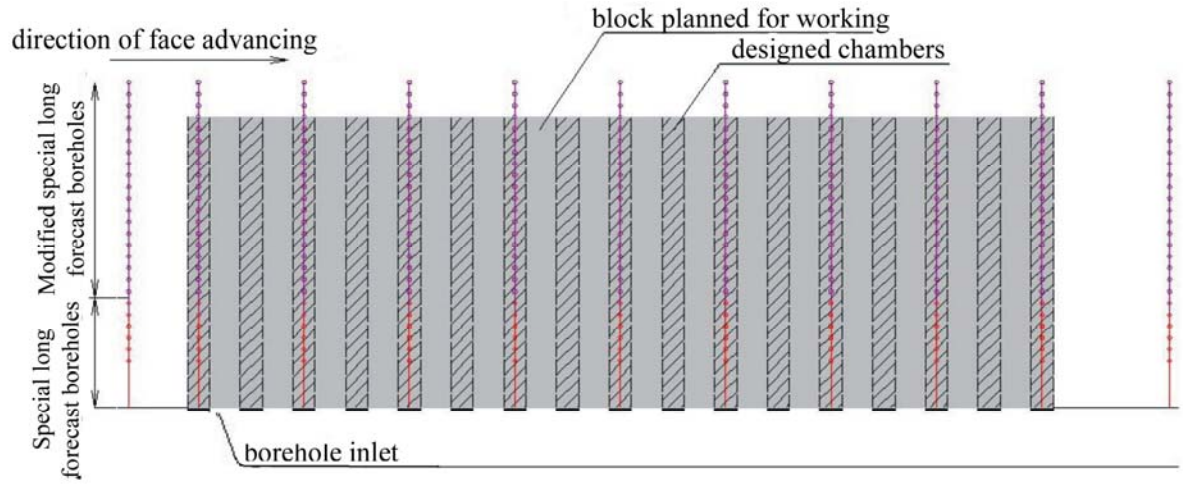

Fig. 1. Borehole pattern for local forecast.

Continuous Forecast

According to Article 7 of Ordinance, the continuous forecast is defined by Clause 4, namely "*The continuous forecast enables the evaluation of a possibility of occurrence of rock and gas outburst in the course of driving of long mine workings and face operation".* The continuous forecast is then carried out according to Article 5 of Instructions, where principles of implementation and evaluations are determined in relevant clauses.

Generally, it is evident that according to valid legislation, in the stage of continuous prognosis, results of forecast boreholes of the same character as with local forecast are utilized; in the new mining method being verified, special long forecast boreholes (SLFB) will be thus used in accordance with Clause 12 of Article 5 of Instructions. To ensure the safety of employees during the mining by drilling, the forecast of gas-dynamic events should be ensured at regular intervals of face advance, both during the advance along the haulage entry and during the advance of drilling into the depth of pillar being mined out. This forecast must be methodically determined with regard to the implementation of boreholes and also of measurements and evaluation of forecast indicators. As well, the determination of measures in the course of verification of unfavourable forecast is necessary.

For the implementation itself it is valid that in the case of mining by large diameter drilling, the continuous forecast will be carried out by means of SLFB in two stages.

1st stage

As for the determination of extent of the zone, in which the continuous forecast by means of SLFB will be carried out, we recommend the extent to be equal to the length of the block being mined out (along the haulage entry) increased by 10 m on both the sides. The length of boreholes and the method of their evaluation are to be determined in accordance with Instructions and critical values according to Instructions for the relevant degree of coal and gas outburst hazard following from the local forecast.

The drilling of all SLFB implemented in the given pillar must be performed in sufficient advance of introduction of the mining machine.

2nd stage

We recommend the implementation in purposefully drilled special forecast boreholes (SFB) in the course of mining. Borehole spacing is based on the position of chambers being drilled and corresponds to the spacing between the centres of safety pillars left between individual chambers. The boreholes will always be drilled in the centres of safety pillars using the diameter from 42 to 80 mm. The length of the boreholes will be determined to exceed the supposed length of chambers (holes) being mined by 3 m. On the mouth, the boreholes are equipped with a tight tamping to the depth of 8 m as a minimum. This depth is, with reference to the risk of outburst occurrence, verified in the course of 1st stage. Through the tamping, a steel pipe ended with stop valves passes; it will be used for the measurement of forecast indicators – gas production rate $\mathbf{q_p}$ and gas pressure **p**; limiting values will be determined according to Instructions. The measurement will be made at intervals, always after the working out of 3 m of each chamber.

What plays a decisive role in the ensuring of the forecast is the maintaining of operation sequence. The recommended procedure for the measurement of parameters of continuous forecast can be determined according to [1] as follows:

1. cessation of winning,
2. connection of the measuring unit to SFB equipment,
3. measurement of gas production rate /q_p/ using a flow meter with the valve turned on,
4. turning-off of the valve of measuring unit,
5. measurement of gas pressure /p/ till a manometer reading is stabilized, however minimally for 4 minutes,
6. disconnection of the measuring unit,
7. closure of the stop valves.

For the whole duration of drilling, the forecast will be ensured by individual observation; this means that the crew will observe dynamic manifestations of the rock mass in the course of drilling (blowing out of coal and gas, strokes, sticking of tools, etc.) and will keep records on them. This information is of decisive importance to SFB evaluation.

A borehole pattern for the special forecast boreholes is clear from Figure 2 given below.

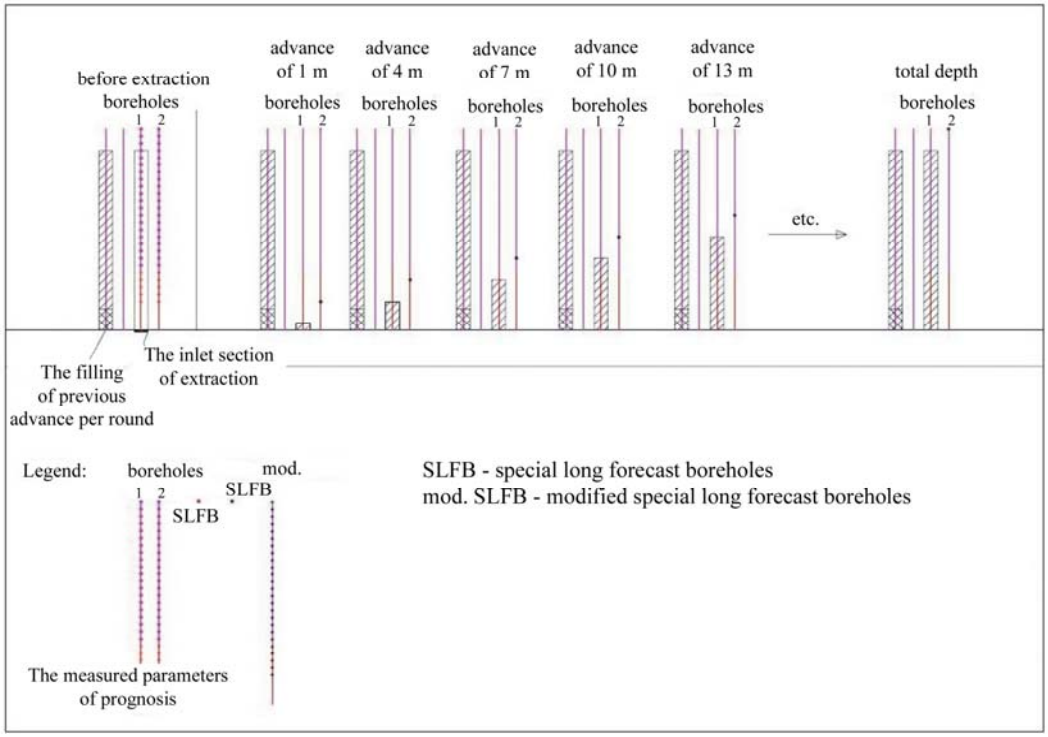

Fig. 2. *Borehole pattern for continuous prognosis (2nd stage).*

In the case of exceeding the limiting (critical) values of forecast parameters, the mining of a specific chamber (hole) will be stopped and that will be tightly closed. The machine will be moved to a new position and another chamber will be mined out. SFB required no longer will be decommissioned by sealing the mouth.

Final Evaluation of the Forecast

Forecast methods for faces, stated in the Ordinance, are elaborated for the method of longwall working along the strike.

For coal mining using the drilling method that utilizes long large diameter boreholes (chambering), such a methodology for coal and gas outburst forecast cannot be applied completely. In principle, the considered system of winning is close to the chamber-and-pillar system; nevertheless, it has its own specifics that must be necessarily taken into account in the case of mining under conditions of hazard of rock and gas outbursts. Thus it will be necessary to adapt the forecast methods to new conditions represented by the application of the new mining method.

With regard to the fact that the new mining method is in the stage of verification and is highly difficult as for the verification of forecast parameters, and with regard to the fact that it is highly hazardous due to a possibility of inducing outbursts, such variant can be chosen when each block being worked will be a priori classed as with the 2nd degree of outburst hazard. Without the implementation of the 2nd stage of continuous forecast, the pillar being mined out will be treated in its whole area using some of the methods of active outburst prevention.

Methods of Prevention in the course of Mining under Conditions of Hazard of Coal and Gas Outbursts

Active Prevention Methods

A set of active prevention methods for ensuring safety against coal and gas outbursts in the course of mining using the method of large diameter drilling is, with reference to the character of the mining process itself, relatively limited. Of available methods, merely the method of seam pressure water infusion can be used without any modification in methodology; classically the pressure water from the mine water distribution system can be utilized as well as high-pressure infusion by group boreholes.

Solutions for prevention utilizing the methods of disintegration of the seam being mined in the whole or in a part of area of interest with using “break free” blasting, stress-relief boreholes are without an extensive and also considerably hazardous verification almost unfeasible, because all the above-mentioned methods are based on pillar weakening, which is however in contrast to the basic necessary condition

of mining with using the chamber-and-pillar method. As a matter of fact, this is just a case of chamber-and-pillar method, namely the preservation of certain strength of block of interest intended for mining out (condition of preservation of the strength of pillars left).

We recommend the infusion of coal pillar by means of long infusion boreholes from the haulage entry for active prevention of coal and gas outburst (henceforth referred to as CGO) origin when applying the new mining method of drilling of coal pillar. These boreholes must be drilled minimally 50 m ahead of the last chamber being mined out in the direction of mining and always must be drilled in the axis of supposed inter-chamber pillars.

After seam infusion, the infusion boreholes will be subsequently used as forecast boreholes – in the framework of 2nd stage of coal and gas outburst forecast. The diameter of infusion boreholes will move in the range from 42 mm to 80 mm.

If the infusion of the coal pillar should be taken as method of CGO prevention, the required amount of water injected into one borehole must correspond to the volume that is calculated from the following relation:

$$Q = 2\,(l + 5)\,.\,R_{ef}\,.\,m\,.\,q \qquad (1)$$

where:

Q	is the amount of water required for infusion, supplied to one borehole,
l + 5	is the length of borehole increased by 5 m with regard to the infusion range [m],
R_{ef}	is the effective radius of infusion according to borehole spacing [m],
m	is the seam thickness [m],
q	is the intensity of infusion [10 l . m^{-3}].

What seems to be markedly more suitable is the progressive technology of high-pressure infusion by group boreholes that uses not only more efficient technical equipment making it possible to increase the length of boreholes drilled from haulage entries, but also combined high-pressure tamping ensuring the perfect sealing of boreholes in the required length (up to 15 m).

The introduction of this technology makes it possible to infuse reliably a group of more boreholes from one source, and leads to an increase in effectiveness and efficiency of coal seam infusion.

As the specific method of active coal and gas outburst prevention, which should be implemented in advance of the commencement of mining and also in the course of mining, we regard the degasification of area of interest, i.e. the area of block being mined out.

Passive Prevention Methods

Passive measures are an indispensable part of outburst prevention. With reference to the character of mining operations performed, for the safety of the crew it is necessary to determine passive preventive measures in the proposed extent as follow:

- In the course of winning, when acting on the pillar, nobody will stay in the area between the chamber being drilled and the end of zone hazardous in the direction of air, and within 15 m from the chamber being drilled in the opposite direction of air.
- The pillar in the close surroundings of the borehole mouth will be cased in adequately.
- In the period if winning, the operating personnel of the mining machine will be equipped with self-rescuers ready for immediate action hung on their bodies. In the course of winning, the other members of the crew will also be equipped with self-rescuers hung on their bodies.
- Within 30 m in the direction opposite to that of air current from the mining machine, a pressure sack will be situated in the fresh air.
- In case of CGO or in case of its indication, the crew will leave the workplace in the direction opposite to that of air current or will shelter in the pressure sack.
- One button for emergency closing the supply of electrical energy will be located on the place of machine operating personnel; the other button will be placed in the pressure sack.
- A mercaptan alarm system will be located in the fresh air about 75 m ahead of the mining machine and in case of outburst or another accident endangering the safety of other workers, the crew will initiate it manually.
- To check the concentration of CH_4 a sensor for methane measurement will be placed in the air exhausted from the workplace (on the side of haulage entry of the space being mined, at the height of the roof of chamber being mined to the distance of 1 m from the point of its mouth).
- The illumination of the workplace and escape roads will be performed by means of air lamps. One lamp will be placed in the workplace near the mining machine, another about 50-75 m from the mining

machine in the direction opposite to that of air current. In the case of a change in gradient or direction of escape road in the given section, other lamps will be placed in these places.

- The area of mine workings in the direction of return air from the position of mining machine will be delimited as hazardous area in the extent determined by the mine manager. On all access roads to the hazardous area, warning red lights saying "no entry" in the course of mining or in the case of increased CH_4 concentration in the return air behind the space being excavated and a table with rules for entry into the hazardous area will be mounted. In these places, telephone apparatuses will be installed as well.
- All the personnel entering the hazardous area or leaving it are obliged to announce their entering/leaving to the inspection service keeping the records on presence.
- The inspection service is obliged to ensure that during the action on the rock mass, no workers are there in the hazardous area.
- If in the course of mining, drill heads reach the surrounding rock and the crew does not succeed in the immediate correction of direction back to the seam, this state will be considered to be an indicator of increased CGO hazard, and the drilling of the hole concerned will be stopped. The mining machine will be moved to the subsequent position.

Conclusion

The proposal for measures to ensure safety with regard to the risk of outbursts was elaborated in a form of project of outburst forecast and prevention that must be approved by the mine manager. This project that will be part of the mining project should be prepared for all the workplaces in a uniform form and should comply with the following recommended content.

The recommended content of the project of outburst forecast and prevention for the mining of coal pillars using the method of large diameter borehole drilling according to [1] is as follows:

- the purpose of space being mined,
- classification of seam in view of the hazard of outburst occurrence,
- classification of mine working in view of the hazard of outburst occurrence,
- implementation of local forecast (performed, not performed, if not performed the extent or method of classification),
- characterization of space being mined (dimensions of chambers – holes, dimensions of safety pillars, chamber mouth casing, etc.),
- characterization of haulage entry of the space being mined (shape, ventilation, support type, etc.)
- natural geological conditions of rock mass,
- mining conditions of rock mass (edges of spaces not worked out, old workings, and others),
- possible predispositions to outburst occurrence,
- characterization of outburst indications,
- evaluation of possible influence of excess stress on the occurrence of outburst, or possible other anomalous manifestations of geomechanical character,
- methods, range, frequency and location of continuous forecast,
- methods and range of active means of outburst prevention,
- methods and range of passive means of outburst prevention,
  a. impermissible concurrence of activities,
  b. highest permissible number of employees,
  c. limitation of works,
  d. others,

- method of elimination of influences of pillars left,
- measures for already driven and used mine workings that are affected by excess stress due to the performed mining activity,
- measures for already driven and used mine workings that can be affected by a possible outburst,
- map supplement – seam map with the marking of edges of spaces not worked out in the roof and the floor and with the marking of influences of excess stress due to them and due to their sources,
- map supplement with the marking of forecast and prevention measures in the locality of interest.

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