MONITORING AND CONTROL OF GAS CONTENTS AND AIRSTREAMS IN GASSY UNDERGROUND COAL MINES

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ABSTRACT

This paper presents the results of research into selection of an optimum system for monitoring gas, fire, and ventilation parameters in the Stara Jama Mine, a brown coal mine of the Zenica Coal Basin in Yugoslavia. It discusses the need to investigate, and logistics of applying automatic controls for gas content and ventilation in coal mines with methane. Remote monitoring of mine air, and ventilation automation systems applied and considered at Stara Jama are presented.

INTRODUCTION

Extraction of coal in underground coal mines is burdened with a number of natural and technological problems which present a danger to life and health of the miners and material resources. Occurrence of explosive, toxic, and suffocating gases; formation of explosive coal dust, oxidation processes, and spontaneous underground fires; sudden outbursts of methane, coal, and surrounding rocks; and increase in temperature and humidity of mine air, all add to the complexity of mine ventilation as a crucial element for safe work.

The scientific and professional experience with catastrophes which occurred in the coal mines of Kakanj, Breza, and Zenica, identifies instability of and disturbances in the ventilation system as the main causes of the formation of methane-concentrations. The explosive concentrations were often ignited by an electric spark. The catastrophes were usually associated with secondary circumstances such as insufficient control of gas contents and ventilation, lack of modern ventilation monitoring systems, inadequate ventilation facilities, large and uncontrolled air losses through isolating structures and gobs, and improper handling and maintenance of electrical equipment. Solutions for these complex natural and technological problems require long-term and costly scientific research. Cooperative research between the Institute and Faculty of Geology and Mining in Tuzla and the U. S. Bureau of Mines in Pittsburgh under the Yugoslav-United States Joint Fund for Scientific and Technological Cooperation, was initiated on conditions governing brown coal extraction, occurrences of explosive and other gases, and applied ventilation systems. The purpose was to select an optimum gas, fire, and ventilation monitoring system. Such systems are not manufactured in Yugoslavia, however those of European manufacturers have been applied in the country for the last 5 years. The selection of a monitoring system for the Zenica mine was based on knowledge of the European and U.S. systems, as well as on experience with their application. The entire research was based on the Stara Jama brown coal mine of the Zenica mine complex as a typical case example of the problems and dangers from methane and underground fires. This paper presents the research results from this study to find a solution for stable and safe ventilation by means of automatic monitoring and control of air distribution in underground workings, thereby reducing the possibility of accumulation of explosive methane-air mixtures.

BASIC DATA ON STARA JAMA COAL MINE

Stara Jama is one of four active underground mines operating within the Zenica brown coal mine complex, and occupies a central part of the Zenica coal basin. The mine was started in 1881. The annual output of the mine is 400,000 tons of commercial coal. The mine was developed with two ventilation slopes and a production shaft. Seven coal seams of various thicknesses and quality have been developed. Currently only the northern part of the mine is active with working of the main coal seam 730 to 911 m deep. The 14 m thick main coal seam is mined in sections by mechanized longwall (Fig. 1), in which the roof seam is mined first, then the floor seam, and medium seam. Presently, the floor seam and medium seam are being mined by a longwall face 150 m wide and up to 2,000 m long.

A larger fault separates the Stara Jama deposit from the adjacent mines, while smaller faults determine the size of the mine section and have a considerable effect on selection of the mining technology. These faults may be related to an increase in the methane emission when the mining is done in their vicinity or through them.

Gas content in a deposit, spontaneous combustion of coal, and spontaneous combustion and explosiveness of coal dust are important to ventilation in a producing area. Methane, hydrogen sulfide, nitrogen oxide (from equipment), and carbon monoxide (from fires) are liberated at the

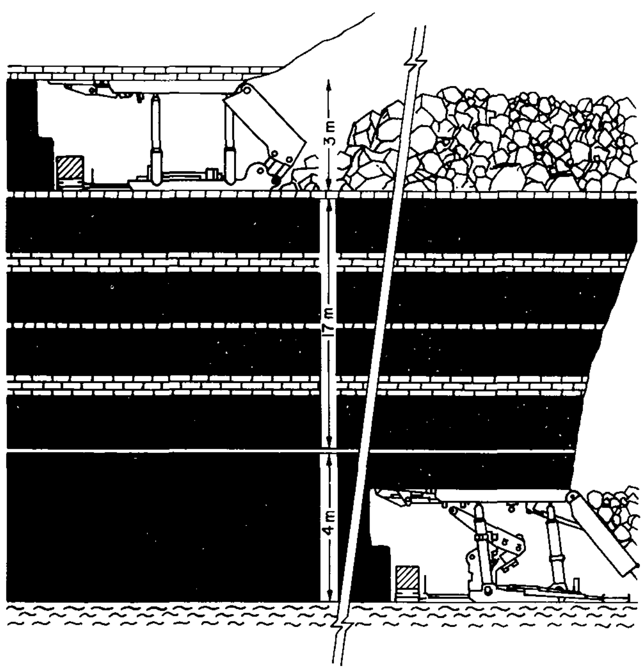


FIGURE 1. - Mining of the main coal seam of Stara Jama Mine

Stara Jama coal mine. The largest emissions in quantity and concentration are methane, whereas emission of other gases are much lower and less frequent.

The coal seams and the surrounding rocks of Stara Jama are significant methane carriers, whose migration is affected by the structure of the deposit. The local tectonics effect is related to the micro-distribution of methane within the deposit, and is considerable in highly disturbed deposits. The Podbrezje fault on the northern side has a 300-400 m displacement which brought the overlying seam and the main coal seam in direct contact with deep floor clay sediments (known as good isolators), thus preventing the migration of methane in this direction. The Stranjani fault caused similar methane isolation in another area. These faults are great barriers to methane migration and natural degasification of coal seams. Other faults further complicate the problems related to methane.

The methane emission in Stara Jama occurs through exhalation from coal seams, release from crevices due to mining, and in the form of "blowers" (release of methane under pressure). For mine safety, methane concentrations in all underground workings are divided into three categories:

Category 1: up to 0.5%
safe level.

Category 2: 0.6-1.0%
warning level--take corrective action.

Category 3: above 1.0%
alarm level--removal of miners, deenergize equipment.

Methane emissions may cause concentrations from 0 to over 1.0%, therefore all danger categories of 1, 2, and 3 can be expected. Total emission of methane is approximately 20 m^3/min. The coal seams are also very prone to spontaneous combustion. Natural inflammability index by Olpinsky ranges from 78 to 110° C/min. The lower explosiveness limit of dust of the main coal seam in the coal dust-air mixture is 170 g/m^3, and 150 g/m^3 in the coal dust-air with 1.5% methane mixture.

The mine is ventilated by one intake and two return airways. The central and western parts of the mine are ventilated by the diagonal system, and the southern part is ventilated by the central system. There are three ventilation sections, southern, western, and central (Fig. 2). The main intake is the main production shaft which feeds to the productive (western) part by the haulage road. The airflow in the production shaft branches off by levels. Air is taken from the haulage road to ventilate the depot and explosive storeroom. The airflow from this section and the main level leaves the mine by the ventilation shaft.

The airflow for the productive part in the main haulage road splits in two parts, one for ventilation of a development entry in the central part and one for entries for longwall development in the western part. The return airflow leaves through the various airways and central slope.

Basic parameters of the ventilation network are:

- Main fan pressure on the central slope: h_1 = 2,747 Pa
- Main fan pressure on the ventilation shaft: h_2 = 343 Pa
- Air quantity in the production part: Q_1 = 2,862 m^3/min
- Air quantity through the ventilation shaft: Q_2 = 515 m^3/min
- Total equivalent mine opening: A_u = 1.377 m^2.

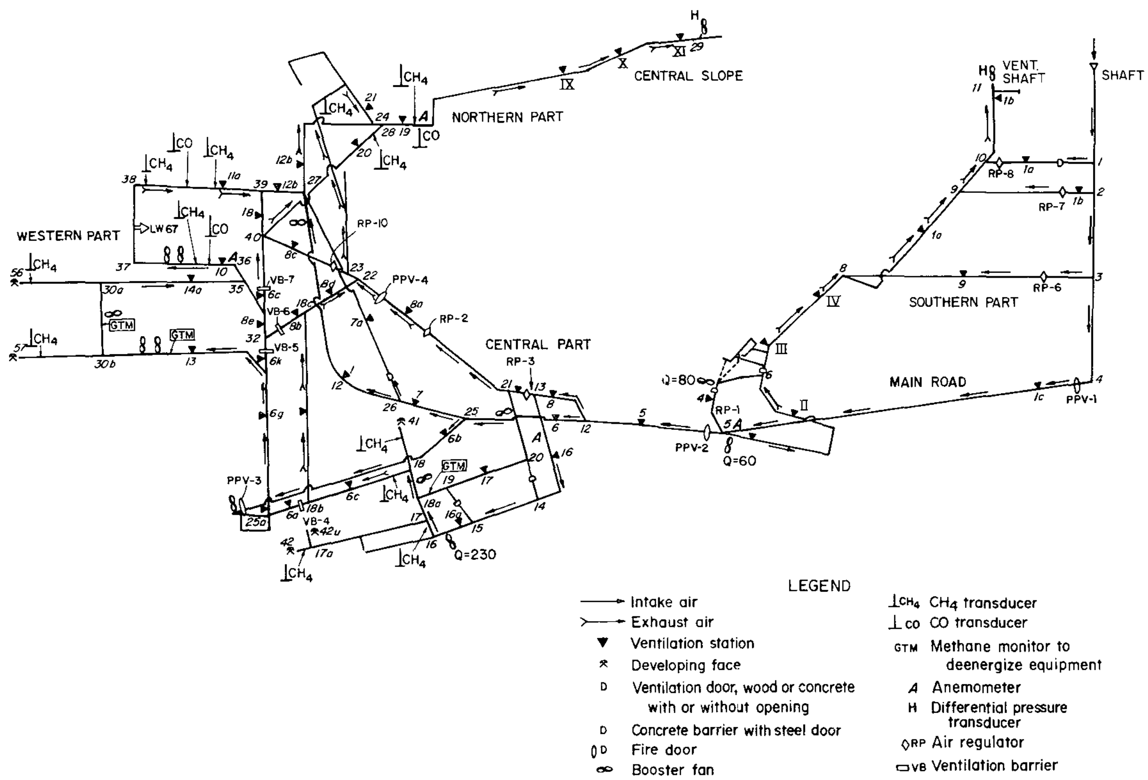


FIGURE 2. - Ventilation diagram of Stara Jama with location of sensors

BASIC REQUIREMENTS OF REMOTE MONITORING SYSTEMS

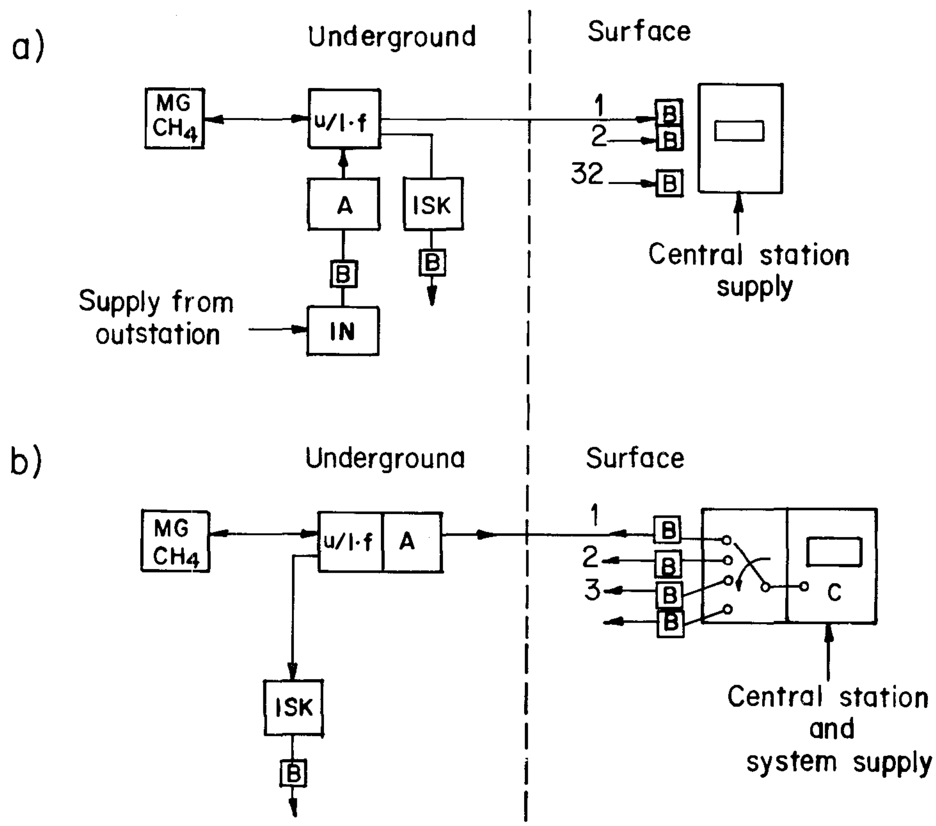
Three basic functions of mine monitoring systems are (1) sensing and measurement of certain parameters (detection), (2) data transmission (telemetry), and (3) data analysis and display.

Specific mine requirements of these functions determine the basic structure of the system (Fig. 3) which incorporates transducers, which monitors and measures the parameters, and converts them into electrical signals. The system must also include outstations, electrical installations for transmission of data from underground transducers to central station or computer on the surface, and the central station or computer on the surface, where the received signal is analyzed, converted to measured value, and displayed or filed.

Data reception and display of the data may be continuous for all connected transducers, or discontinuous-cyclic, for one transducer at a time. Transducers contain current circuits and measuring elements (head, sensor), and circuits for conversion of current or voltage signal received from the measuring head into the corresponding code signal for transmission to the central station or computer. The measuring head may be in the same enclosure with the converter unit, or placed in a separate enclosure.

The measuring head output can be a simple status indication, called a binary, contact closure or status output (high-low, open-closed), or it can be a continuously variable function of time, called analog output (air velocity, methane concentration, etc.). The analog outputs can provide much more information so they are used for monitoring the environmental parameters, whereas the simple status outputs are used to monitor the equipment parameters.

Transmission of data from the transducers to the central station



KEY

IN	Supply source
A	Battery
U/I	U/I or U/f converter (encoder)
ISK	Switch-off relay
MG	Measuring head(transducer) CH_4
C	Central station
B	Barrier

FIGURE 3. - Basic structure of mine monitoring system

on the surface is done by special cables (pairs) for each transducer, or several cables are connected to the outstation in which the signals are encoded and transmitted in a common cable to the central station. In selection of a method for transmission of several signals in a common cable, the system technically identified as frequency domain multiplexing offers certain advantages. It makes possible a simultaneous and uninterrupted transmission of all data within the overall frequency range of the system, whereas, when time domain multiplexing is used, the signals are received and transmitted cyclically, at time intervals necessary to receive and analyze the data from all measuring points.

The central station or computer on the surface should provide the following:

(1) Recording, display, analysis, and storage of data received from the underground transducers. This should be provided for methane, carbon monoxide, carbon dioxide, and oxygen contained in the mine air, velocities of the main or

separate airstreams, temperature of mine air, and positions of air regulators and ventilation doors.

(2) Signaling of excess over the predetermined thresholds of measuring data in two stages (warning and accident condition).

(3) Automatic deenergization of equipment in the hazardous area or in the whole mine, depending on design solutions or requirements of technical standards.

(4) Checking of each line and the entire system for proper functioning, and signaling of defects found in the system.

As the mine monitoring systems should increase the safety of mines and miners, one of the requirements imposed on them is reliability of the system itself and a constant transmission of accurate data. Reliability is particularly important because of the seriousness of problems that could develop in an inflammable and explosive environment. The systems must provide early detection of fires, and provide rapid warning and deenergization of electrical equipment.

The above stated circumstances require a proper selection of a monitoring system, its installation, operation, and maintenance. A deficiency in any of these stages, regardless of whether it is a fault of the manufacturer or the user, may lead to serious consequences.

Reliability of mine monitoring systems in inflammable and explosive methane-air mixtures necessitates an intrinsically safe explosion-proof design (Exia) of the entire underground part of the system. Since the system is connected to surface and underground electrical networks which are not intrinsically safe circuits, it is necessary to install barriers on all lines connecting the system to other networks, to secure a separation of intrinsically safe circuits from those that are not.

Guaranteeing a continuous supply of data on the monitored parameters requires a duplication or even triplication of certain elements, or the entire system. The duplication should be made in such a way that one breakdown or defect would not cause a failure of the entire system. This is a much more expensive solution, but at the same time it insures that no alarm signal may pass unnoticed. Both the software and the hardware part of the system must be reliable. Based on the analyses made by U. S. Bureau of Mines research, a conclusion was made that the central processor unit (CPU) on the surface should be duplicated and that transducers should also be duplicated. The data transmission systems should be designed with double independent cable installed in separate entries to prevent the signal loss in case of damage to one cable by fire or roof fall.

Another requirement is the accuracy of received data. Sensitivity of a system to transmission of incorrect data depends on several factors such as type of cable, local field of electromagnetic noise, cable length and shape of the signal. Research at the U. S. Bureau of Mines showed that the maximum transmission distance for one undetected random error/year ranges from 2,100 m to 10,950 m in an average noise field, and from 160 m to 965 m in an estimated maximum noise field. Therefore, in mine monitoring data communication systems, one must take into account the fact that transmission of undetected errors will sometimes occur.

Reliability of the monitoring system software program is also a factor of considerable importance, since it is difficult to be certain that all errors and defects have been detected and removed from the software. Optimally, to reduce the chance of software errors, software should be developed by two independent programmers, and then run on two separate processors to compare the results and determine whether all possible bugs and errors have been removed from the program.

In addition, it is necessary to stress the importance of transducer accuracy regarding their capability to eliminate the effect of other parameters when measuring desired parameter. Important also are the quality of all system elements with respect to operation in the mine environment. Modern design technology must be practiced.

1.0 to 24.0 m/s in ventilation tubing, and

- differential pressure from 0.0 to 5.0 kPa.

Basically, the system consists of:

(1) transducers installed in the mine for measurement of the above parameters,

(2) transmission of outputs, individually or directly from the transducers to the central station; and

- automatic switching to standby battery supply in case of power failure in the network;

- capability of testing of the standby supply and adjusted alarm levels;

- multiplex transmission of signals from underground to the dispatching center on the surface;

- explosion-proof design of transducers and cabling.

In addition, the methane transducers should be able to automatically deenergize the electrical equipment in the endangered part of the mine, or the whole mine.

The following should be provided by the central station at the dispatching center on the surface:

- monitoring and processing of data from the mine;

- alphanumeric display of transducer outputs during normal and alarm conditions;

- color display of mine and measuring point schematics;

- recording and storage of received data in a data base;

- checking of data transmission lines for proper performance including failure, short-circuit or switch-off.

Based on the above requirements and analysis of the existing CTT 63/40 U system, it was concluded that the existing system does not provide

- installation of a new system from Sieger, Great Britian, and EI Nis, Yugoslavia, and utilization of the existing system for other mines;

- installation of a new system of U.S. production, which would fully comply with the defined requirements.

The new CGA system is considerably improved with respect to the CTT 63/40 U and has the following features:

- All transducers have local (on the transducers themselves) digital display of the measured parameters, local adjustment of the alarm level, and local alarming if the threshold limit is exceeded.

- Multiplex transmission of 8 output signals to the surface by a paired cable.

- The signals from the mine are received and processed in a microcomputer on the surface, which is connected to the control board, display panel, two alphanumeric printers, and a central control unit.

The British Sieger system also provides all the required features, while data transmission to the surface and a computer with full processing and display are produced by EI Nis. This system operates successfully in some Yugoslav mines.

The American system has all the required features. The computer can be connected to the control board, display units, and printers.

monitoring, will represent an integral solution to the safety of mines and miners.

LOCATIONS OF MEASURING POINTS

It is important that the monitored data accurately reflect the status of the mine environment. Fulfillment of this requirement necessitates the proper arrangement of transducers for the monitored parameters in the system of underground mine entries.

Measuring point locations generally are along the underground entries and points in an entry cross-section.

Location of the measuring points along the underground entries is usually determined by requirements of regulations for control of a particular parameter, such as ventilation method, and actual degree of hazard. Location of the measuring points in cross sections of underground entries are determined by physical properties of the measured parameter with respect to ventilation air, arrangement of equipment within the entry, or entry characteristics affecting the point at which the parameter is to be monitored.

In principle, the methane transducers are placed in the main intake and the main return ventilation entries, intake and return entries of longwall faces, return entries of development faces, and other locations where there is a need for continuous monitoring.

Carbon monoxide transducers function as a means for protection of miners from being poisoned by carbon monoxide and as early detectors of spontaneous underground fires. They are located in the area where the oxidation process may be expected, such as in the vicinity of mined-out areas, intake and return entries of longwall faces, and in the vicinity of faults. Another area of placement is near equipment locations such as in belt haulage entries. They are placed in the middle of entries.

Air velocity transducers (anemometers) are placed in all major branches of the ventilation network. Location in a cross section of an entry is at 2/3 of the entry height.

Differential pressure transducers are placed before the main fan to measure the pressure difference in the main airflow, and in other places where the pressure difference ought to be controlled.

The location of transducers of gas, fire, and ventilation for Stara Jama followed the above rules. The arrangement is as follows (Fig. 2):

(a) methane transducers

- in all separately ventilated underground mine entries (at 3 and 20 m distance from the face on the opposite side of the entry from the ventilating tubing);
- in return airflow of ventilation sections;
- in intake and return airflow of longwall face (at 20 m from the face in haulage road and airway);
- in areas of the ventilation system with separate ventilation of workings;
- in main intake entry of the mine;
- in other underground mine entries in which special methane conditions might occur.

(b) carbon monoxide transducers

- in intake and return entry of longwall faces;
- in main intake entry in the mine;

- in main return entry of the mine;

- in return entry of the productive part of the mine;

- in return entry of the longwall panel GPP-VI;

- in return entry of southern part of the mine.

(c) air velocity transducers

- in intake and return entry from longwall face;

- in intake and return entry of ventilating sections;

- in intake entry of productive part in the mine;

- in intake entry of southern part of the mine;

- in intake entry of deep section of the mine;

- in intake entry of the longwall panels;

- in return entry of separately ventilated workings or in the separate tubing at 20 m from its end in cases where controller of the separate ventilation has not been installed.

(d) air temperature transducers

- in intake and return entry of longwall faces;

- in main intake entry of the mine;

- in main return entry of the mine;

- in intake entry of productive part of the mine.

(e) differential pressure transducers

- at main ventilation fans.

According to the position of mining operation in the mine ventilation system, scope of mining operation and gas parameters, the arrangement of transducers must be adjusted to provide full monitoring of gas contents and airflow.

CONCLUSION

Application of a monitoring system for gas contents and airflow in coal mines with methane represents a considerable contribution to securing safe mining conditions. Environmental monitoring must accurately represent the actual conditions in the mine. It is important to select a system which best provides for monitoring of the specific mining conditions and dangers in the mine. Data obtained by this system make an excellent basis for determination, and timely application of safety measures. It is planned that a monitoring system will be purchased by Stara Jama Mine for its operations which meets the discussed requirements.

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SURVEILLANCE ET CONTROLE DE LA TENEUR EN GAS ET DE L'ECOULEMENT D'AIR DANS LES MINES GRISOUTEUSES SOUTERRAINES DE CHARBON

Milutin Vukic, Jeffrey H. Welsh

La modernisation rapide des mines de charbon grâce à l'introduction d'équipements électriques à haute tension, de vastes réseaux d'appareils et d'installations, ainsi que de l'exploitation à grande échelle de charbon à des profondeurs de plus en plus importantes, a eu pour conséquence l'apparition de gaz explosifs, toxiques et suffocants, de phénomènes d'oxydation et de combustion spontanée, ainsi que l'élévation des températures et de l'humidité de l'air minier. En raison de tous ces facteurs, la ventilation des mines est devenue un élément crucial, de plus en plus complexe, d'un processus technologique visant à donner aux mineurs des conditions de travail sûres.

Une recherche scientifique a été effectuée sur le fonctionalisme et la fiabilité des systèmes de surveillance du gaz et de la ventilation; cette recherche porte sur les conditions spécifiques de la technologie minière, sur la ventilation et sur les teneurs en méthane des filons de charbon. Des systèmes intrinsèquement sûrs ont été proposés, ainsi qu'une définition des paramètres de gaz, de flammes et de ventilation, et des meilleurs emplacements des appareils de mesure.

ÜBERWACHUNG UND KONTROLLE DES GASGEHALTES IN GRUBENWETTERN IN GASHALTIGEN KOHLEGRUBEN

Milutin Vukic, Jeffrey H. Welsh

Die rapide Modernisierung der Gruben durch die Einführung von elektrischen Hochleistungsausrüstungen, große verkettete Einrichtungen und Installationen, konzentrierte, groß angelegte Kohleproduktion in immer größeren Tiefen, das Auftreten von explosiven, toxischen und erstickenden Gasen, Oxidationsvorgänge und Selbstentzündungen, sowie die steigende Temperatur und Feuchtigkeit der Grubenluft machen die Bewetterung der Grube als kritische technologische Sicherungsmaßnahme für den Arbeitsplatz immer schwieriger.

Eine wissenschaftliche Untersuchung der Funktionalität und Zuverlässigkeit der angewendeten Methangas- und Wetterungsüberwachungs-Einrichtungen wurde im Hinblick auf spezifische Bedingungen durchgeführt, die die Technologie des Abbaues und der Ventilation, sowie Methangasgehalte der Flöze beeinflussen. Eigensichere Einrichtungen und die Definition von Gas-, Feuer- und Bewetterungsparametern, sowie die optimale Verteilung von Einrichtungen zur Erfassung derselben werden vorgeschlagen.

СЛЕЖЕНИЕ И КОНТРОЛЬ НАД УРОВНЕМ СОДЕРЖАНИЯ ГАЗА И ВОЗДУШНЫМИ ПОТОКАМИ В ПОДЗЕМНЫХ УГОЛЬНЫХ ШАХТАХ С ВЫСОКИМ СОДЕРЖАНИЕМ ГАЗА

Милутин Вукич, Югославия; Джеффри Х. Велш, США

Описываются условия ускоренной модернизации угольных шахт путем введения мощного электрического оборудования и сети приспособлений и установок, а также концентрированная и крупномасштабная добыча угля на более глубоких горизонтах. Указывается значение таких факторов, как появление взрывоопасных, токсичных и удушающих газов; процессы окисления и произвольного возгорания в шахтах, а также повышение температуры и влажности воздуха в шахтах. Технология строительства вентиляционных систем в шахтах становится все более сложной, и значение вентиляции для обеспечения безопасности труда шахтеров увеличивается.

Было проведено исследование функциональности и надежности систем слежения за содержанием газа и вентиляцией. Особое внимание было уделено специфическим условиям, воияющим на технологию добычи, вентиляцию и содержание метана в угольных пластах. Предлагается введение сложных систем, обеспечивающих безопасность, а также определение газовых, пожарных и вентиляционных параметров и оптимальное местоположение датчиков, использующихся для их измерения.

瓦斯型地下煤矿中煤气及空气流的监测与控制

密鲁丁.傅克依屋
杰弗里 H. 威尔希

强力电气设备的引进使煤矿高速地现代化起来，设施和设备的大型网络化，集中型煤炭的大规模高深度开发，瓦斯爆炸，中毒和窒息，煤矿内的自发性爆炸以及矿内空气湿度与温度的增高，这些都使得矿工安全作业的矿井通风问题愈来愈复杂。

本文科学地探讨了在各种不同的采矿方式，通风设备和煤层甲烷含量情况下，气体和通风监测系统的使用性能与可靠性。本文建议使用内在性安全的系统，同时确定了气，火和通风参数的定义以及测量这些参数仪器摆设的最佳位置。

U.S. BUREAU OF MINES
OPEN FILE REPORT
OFR 27-89

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第23届采矿安全研究学院国际会议

Washington, DC
September 11-15, 1989

Organized by the U.S. Department of the Interior, Bureau of Mines