10 ANALYSIS OF GASEOUS HAZARDS IN MINE WORKINGS USING AN AUTOMATIC MONITORING SYSTEM

10.1 Introduction

One of many dangers in mine environment, the most essential concern changes in composition of fringe drift air. Danger example in mine environment can be to high concentration of methane or coal dust, which endanger the safety because of explosion or to high dangerous gases concentration (eg. CO_2, H_2S, NO_2, etc) and changes in oxygen amount in the air possibility [1]. In industrial safety law, there is defined acceptable level of occupational risk. This risk is defined by the maximum allowable concentration (MAC) and the maximum intensity (MAI) factors harmful to health in work environment [1, 2]. Changing atmosphere parameters in fringe drift should be constantly controlled. In KWK Mysłowice mine this serves as the automatic monitoring system of gas hazards. System works by controlling air parameters, which are observed and recorded by measuring and monitoring devices. This equipment has signaling device to warn about hazard.

10.2 Atmosphere parameters in fringe drifts

To perform mine works in underground conditions, there must be kept parameters of mine atmosphere. The main task of the ventilation system in mains is creating and keeping conditions similar to those on the surface. The mine atmosphere is constantly polluted by harmful gases produced during mine works, so it is important for safety reasons to make the monitoring system work properly and control mine gases like oxygen, nitrogen, carbon dioxide, carbon monoxide, hydrogen sulfide, sulfur dioxide, nitrogen oxides and methane [3, 4].

The oxygen content in air, accordance with the provisions, not be less than 19% and quantity of air into the fringe drift should ensure the proper one composition and temperature.

The composition of the air does not meet the requirements of people withdrawing because at low concentrations of oxygen the body can not function properly. Oxygen is supplied to the mine workings with mine air through ventilation. On degree of air consumption and a reduction oxygen in the fringe drift influence:

- Air consumption by humans,
- Release of gases from the rock,
- Various types of underground explosions and fires,
- Use of internal combustion engines,
- Rotting wood,
- Oxidation of carbon [4].

Nitrogen is an inert gas, tasteless and odorless, has no effect on the process of respiration and combustion so it is not harmful to the human body. Other mine gases are carbon dioxide and carbon monoxide. Carbon dioxide gas is colorless, tasteless and odorless, heavier than air. At low concentrations, is not harmful, but in larger doses is dangerous. It is a suffocating gas. The maximum allowable concentration (MAC) is 1%. Carbon dioxide produced during respiration, decomposition of organic matter, oxidation of coal, the use of internal combustion engines, use of explosives, the explosion of methane and underground fires. Carbon monoxide is a colorless gas, odorless and at concentrations ranging from 13% to 75% of it has explosive properties. This is a high poisonous gas. The maximum concentration of CO is 0.0026% or 26 ppm [3, 5].

The most common gas in the mine atmosphere is methane. It is a colorless gas, without taste and smell. Methane has explosive properties only at concentrations of 5 to 15%. At a concentration of less than 5% methane, the gas is burning around the source of heat [3]. Mining regulations prohibit any work on methane concentrations above 2%.

10.3 The monitoring system of air in fringe drifts

The development of technical methods and measures for monitoring the automatic control systems significantly reduced gas hazards and the risk of fire occurring in Polish mines. Thanks to these hazards can be controlled with automatic control systems to prevent the initiation or development of hazard. It is now believed that the development of reliable systems (based on continuous measurements) for the monitoring and control of natural hazards is necessary and has a huge impact on the level of safety. The specific conditions forming atmosphere in mine workings confirm the validity of comprehensive solutions making use of modern and reliable automated systems security [6].

Dispatching monitoring system of safety parameters is a set of working together intrinsically safe devices controlling and testing ensure a comprehensive monitoring of safety parameters and production in the underground parts of mines. On the surface the system is connected to a central station computer where the information from the control and measurement devices placed under the ground are available for dispatcher. The system allows conduct complete monitoring parameters of atmosphere in the underground workings on the basis of measurements:

- Physical parameters and chemical composition of air,
- Status and parameters of ventilation equipment.

The monitoring system of atmosphere parameters in the mine (in particular its structure) meets the basic requirements for mine monitoring systems such as:

- Feasibility of mining adopted a hierarchical system of management,
- Power supply for devices of underground part from the surface part regardless of the concentration of methane in fringe drifts,
- Feasibility of automatic notification of crews working in the threatened person area,
- Integration of the system running on a computer surface network with geophysical systems to enable the development of automated pre-emptive exclusion of electricity in areas where the threat occurred,
- Cooperation (download and / or transmission of data through a computer surface network) with visualization systems of data working in the mining,
- Execution of the tasks required by the regulations, in particular:
  - Data visualization,
  - Archiving and reporting,

- Two-stage control of underground the power and signaling devices [7, 8].

The central part of the system is the telemetry system. As part of the surface is made up of central telemetry, the underground part of the field devices (mine). Equipment belonging to the surface part of the monitoring system are:

- Computer Dispatch station implements the functions of monitoring, alerting, reporting and archiving of measurement data,
- Telemetry panel.

While part of the underground system for monitoring safety parameters are:

- Central methane detectors
- Mine intrinsically safe device approved type, adapted to cooperate with the output circuits of central surface
- Intrinsically safe sensors and actuators connected to the underground facilities of cooperating with the output circuits of central surface [7, 8].

The monitoring system operates as a system of two threshold warning. Signaling includes a warning and alarm threshold concentration of gases. In the system oblige the following rules and signaling states of measured values:

- indication of the value of the measuring devices remaining at levels considered normal, are displayed in green or a green background,
- Indicating the value of measuring devices express exception to the normal level, which could lead to a state of emergency (the warning) is displayed in yellow or yellow background,
- Indication of the alarm and faults of devices are displayed with red color attribute.

The red alarm is connected off electricity and the evacuation of employees from the danger zone [7, 8]. Devices operating under the earth, which are permitted and may cooperate with the central telemetry unit can be divided into a continuous and cyclical unit of action. For devices with continuous action include all types of methane and pit centrals. Whereas for equipment having a cyclic action include sensors, signal converters and disable devices.

10.4 Analysis of air in fringe drift

Due to the specific threats in the analyzed coal mine, in the monitoring system should be used the following devices: sensors of methane, anemometers, carbon monoxide sensors, temperature sensors, smoke detectors, barometers, sensors of rock, dustmeter. In the system monitoring of work safety parameters in coal mine Mysłowice work about 150 sensors of methane, carbon monoxide sensors 10 and 30 anemometers examining air flow, placed on two main levels of extraction: 465 m and 665 m. Equipment working underground is far more than required by law, because any place where there is a risk the appearance of methane is monitored by sensors mounted additionally. The location of the sensors determines ventilation engineer, and the amount of sensors is dependent on the needs and constantly changing with the situation in the exploited rock mass.

A large number of sensors, automatic measurement of gas concentration and air velocity included in the gas monitoring system allows for early detection and location of the hazard. Therefore can limit the possibility of inflammation of methane and avoid its tragic consequences. Functions of the monitoring system can also be used during rescue operations, and automatic sensors for tracking changes in gas concentrations at both the air flow control (adjustable ventilation) as well as for isolating wall, eg in a fire.

10.5 Analysis of the threshold concentration of methane in air in fringe drift

The study reported exceedances of alert thresholds in the automatic monitoring system showed that in the one year was about 3500 exceedances of the threshold concentration of methane, an average about 300 incidents exceeded the limit values of methane per month. Of all the sensors of methane, which has been exceeded alarm thresholds can distinguish those in which:

- Was the highest number of exceedances,
- Duration of a single exceedance was the longest.

Tab. 10.1 summarizes the methane sensors marked with the amount of exceedances recorded in the selected (example) a month. The sensors with the number 535 and 346 reported the greatest number of exceedances of the concentration of methane. However, from the list in tab. 10.2 shows that the longest persistence times exceedance concentration of methane in the same month was recorded on the sensor with number 143rd. Sensors for the above analyzed the cause of exceedances in the most natural phenomena are accompanied by exploitation of the deposit. Phenomena such as increased methane concentration after loose layer of carbon in the forehead while mining ancestor of the events a pattern of systematic and involves a risk that must be monitored.

Tab. 10.3 lists the most common causes of record exceeded of threshold for methane concentration by the methane detector 535th issue. The reason for the longest durations of exceedances of the threshold concentration of methane recorded by the methane detector number 535 was an increase in the evolution of methane after loose layer of carbon in the forehead (up to 30 min) and damage to the auxiliary ventilation devices (up to 16 min).

Tab. 10.1 The sensors, which recorded the highest number of exceedances of the alarm threshold methane concentration in a particular month

No.	**No methane sensor**	**Number of exceedances of the month**	**The threshold sensor in ppm**
1.	535	53	1
2.	346	51	2
3.	115	25	2
4.	336	15	1,5
5.	546	14	0,5
6.	106	14	2
7.	349	11	1
8.	343	10	1
9.	502	10	1

Tab. 10.2 The sensors, which recorded the longest persistence times exceedance alarm threshold methane concentration in a particular month

No.	No methane sensor	The time of exceedances in minutes	The threshold sensor in ppm
1.	143	185	0,5
2.	143	179	0,5
3.	143	176	0,5
4.	336	81	1,5
5.	336	70	1,5
6.	537	69	2
7.	114	63	1
8.	516	62	2
9.	346	62	2

During the mining of coal mining and hauling is too large increase of methane, so that it can be discharged by general ventilation and auxiliary ventilation devices. Then there is the methane concentration exceeded, the exclusion of electricity by methane detectors recording and withdrawal of the crew of endangered places it has been brought to the operating conditions to a safe state. Fig. 10.1 shows the physical location of sensor 535, in the area of ventilation in the seam 501 Bw.

Tab. 10.3 Common causes of registered exceedance of alarm threshold methane concentration by the methane detector number 535 in the selected month

No.	Number of exceedances for sensor No. 535	Reason for the alert threshold
1.	8	The increase in methane after loose layer of coal while mining
2.	32	The increase in methane after loose layer of carbon in the forehead
3.	5	The increase in methane after loose layer of carbon in the forehead, barometrical reduction
4.	2	The increase in methane after loose carbon layer, damage to the auxiliary ventilation
5.	2	The increase of methane during the installation of a new air ventilation pipe in the forehead
6.	1	The increase in methane during construction of auxiliary ventilation
7.	3	The increase in methane, occasional lack of compressed air in the auxiliary ventilation devices

The sensor methane No. 143 registered exceedance that lasted the longest of all recorded in a particular month. This is due to location of the sensor. It is mounted in the storage reservoir at a distance of about 2 meters below the level of the tank. Deployment of sensors in the area shown in fig. 10.2.

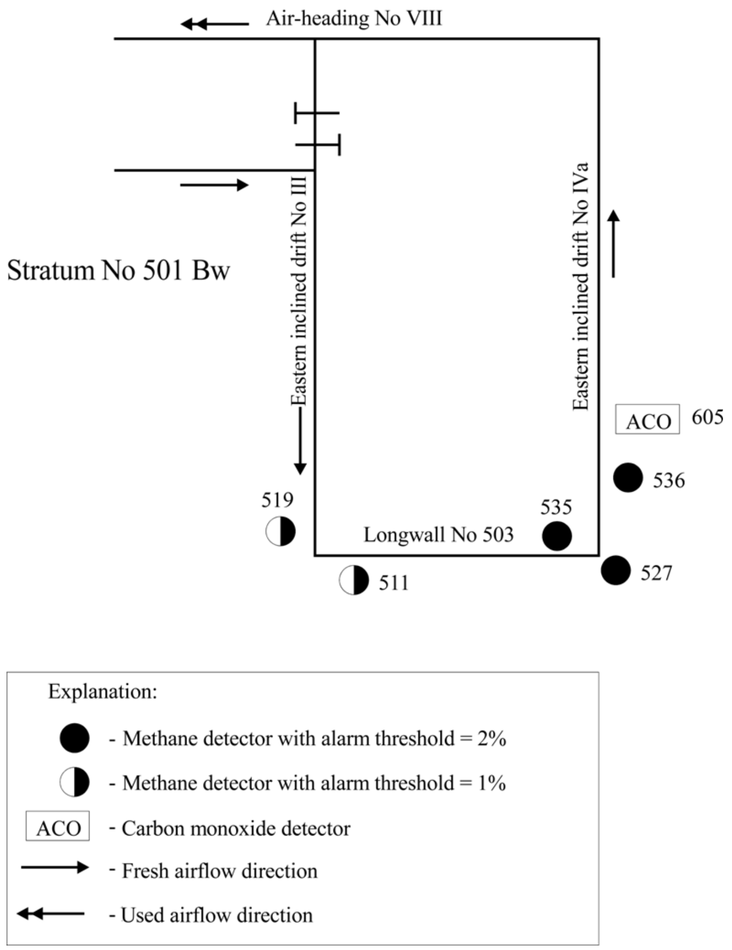

Fig. 10.1 Deployment of sensors in the area methane sensor with No. 535th.

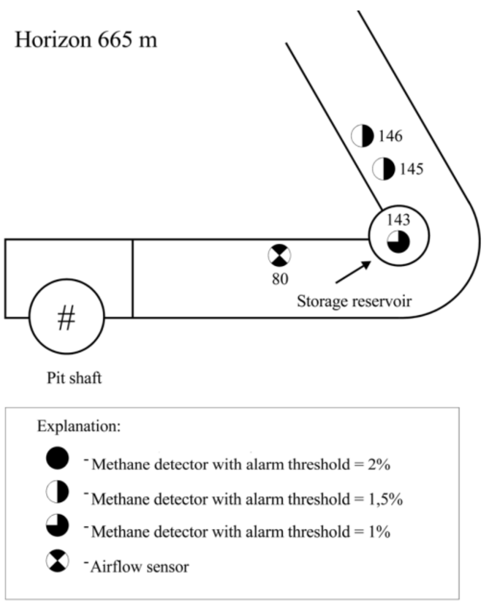

Fig. 10.2 Deployment of sensors in the area of methane sensor No. 143rd.

In the tank in case of failure of the shaft is accumulated carbon. This sensor is required by mining regulations, which is due to the accumulation of large amounts of coal, which emits into the air degassing methane. Tab. 10.4 shows the longest threshold methane concentration recorded at sensor No. 143rd.

Tab. 10.4 Longest exceedance of methane threshold concentration and their causes methane gas detected by the sensor with number 143 in the selected month

No.	The time of exceedances at sensor No. 143 in minutes	Reason for the alert threshold
1.	185	The increase in methane in the reservoir, supply 70%, leaving the winning
2.	179	The increase in methane in the reservoir, supply 80%, leaving the winning
3.	176	The increase in methane in the reservoir, supply 70%, leaving the winning
4.	27	The increase in methane in the reservoir, supply 80%, leaving the winning, barometrical reduction
5.	1	The increase in methane in the reservoir, supply 80%, leaving the winning, barometrical reduction

Analysis of air flow and concentrations of carbon monoxide in the fringe drift

An important parameter monitored by the system is also the concentration of carbon monoxide in the fringe drift. The criterion for selection of sensors for the analysis was the number of exceedances of the threshold limit concentration of carbon monoxide in the air. In the analyzed month the alert threshold were recorded at six carbon monoxide detectors, which is shown in tab. 10.5. Analysis of the causes of alarm conditions detected have been subjected two carbon monoxide detectors Nos. 56 and 241st.

Tab. 10.5 The sensors, which recorded the alert threshold for carbon monoxide in the selected month

No.	No carbon monoxide sensor	Number of exceedances in the month	The threshold sensor in ppm
1.	56	4	26
2.	241	3	26
3.	51	1	26
4.	656	1	26
5.	422	1	26
6.	405	1	26

Carbon monoxide detector number 56 recorded 4 exceedances in the month, and all occurred after the passage diesel monorail. This sensor is mounted in the fringe drift at horizon 465 m. This board has no methane hazard and can therefore work there combustion machinery. However, when employees do not ensure the closure of the ventilation there is a sudden disturbance of ventilation, and the sensor is registered increased levels of carbon monoxide.

Tab. 10.6 shows the causes of recorded exceedances of alert thresholds for concentrations of carbon monoxide detector No. 56 and No. 241st.

Carbon monoxide detector No. 241 is located at 665 m east in stratum 510 D near methane sensors with numbers 109, 115 and 106. This stratum is the fourth category of methane hazard. Carbon monoxide gets into the heading of the abandoned workings of the wall. Location of carbon monoxide detector number 241 and neighboring sensors shows fig. 10.3.

Tab. 10.6 The most common cause exceeding of the alarm threshold of carbon monoxide by the sensor with number 56 and 241st.

No. sensor	The time of the exceedances in minutes	The threshold sensor in ppm	Reason for the alert threshold
56	1	26	The increase of carbon monoxide in the reservoir , passage diesel monorail
56	1	26	The increase of carbon monoxide in the reservoir , passage diesel monorail
56	1	26	The increase of carbon monoxide in the reservoir , passage diesel monorail
56	2	26	The increase of carbon monoxide in the reservoir , passage diesel monorail
241	1	26	The increase in carbon monoxide from abandoned workings, rainfall stone slab in the myocardial wall and heading
241	1	26	The increase in carbon monoxide from abandoned workings, ventilation pipe damaged in a recess in the wall outlet
241	1	26	The increase in carbon monoxide from abandoned workings, stone slab fall, damaged air-lock

The state concentrations of carbon monoxide or methane very often determines the amount of flow of air through the fringe drift. The movement of air is forced through the ventilation flowing and constantly monitored by anemometers. In the month too little air movement, or even its absence was recorded for 9 air flow sensors. The sensors Nos. 58 and 63 alerts were reported most frequently and were respectively 18 and 11 incidents of alarm.

Air flow sensor number 58 is located in the locomotive depot in the charging a battery chamber at horizon 665 meters. In this area there is the fourth category of methane hazard. Failure to close air stopping causes improper air flow, which is shown on the air flow sensor. Air flow sensor No. 63 is attached to the outlet of the water-headings between the crossing of water-headings No. 1 and water-headings No. 2 at horizon 665m. In this area there is the fourth category of methane hazard. This sensor by measuring the air flow also may indicate a dangerous rise in water level in the water-headings. At each level there are so called water-heading located slightly lower than the other, and if necessary the first to be flooded. The anemometer is mounted for recess and when the water will flood the heading entirely or partially closing air flow, water pumps are switched on to restore the normal flow of air.

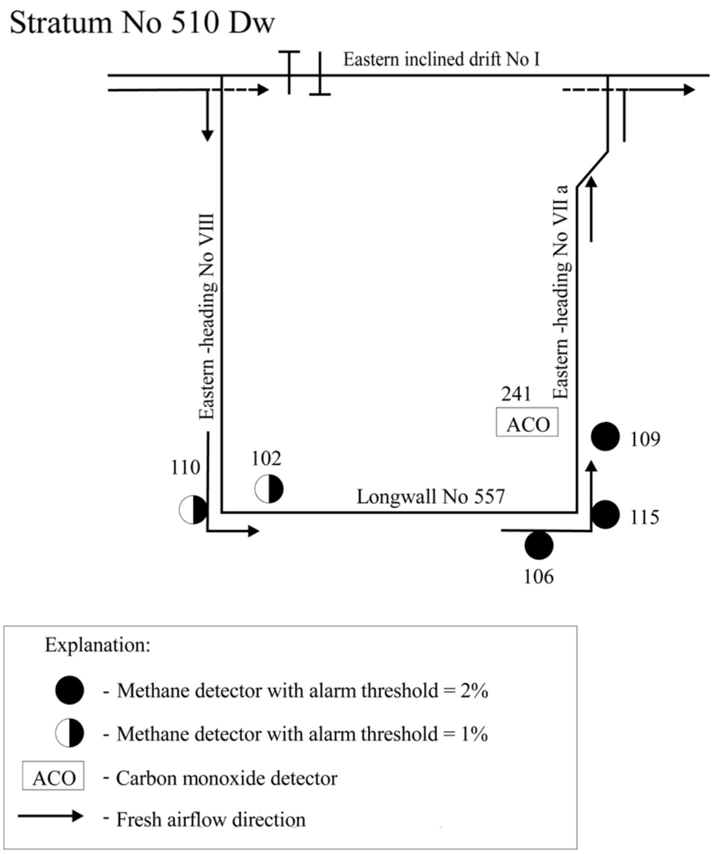

Fig. 10.3 Deployment of sensors in the environment of carbon monoxide detector with a number 241st

10.6 Summary

Examined the monitoring system of safety parameters of the atmosphere in the fringe drift can be used by the dispatcher and the mine management in planning and controlling safety. The whole system of monitoring the risks and working in the large number of sensors for automatic measurement of parameters such as gas concentration, air velocity allows for early detection and location of the hazard. Natural hazards become more severe with the depth of mining, are located in the deeper layers, from which the coal is mined natural risks are higher and working conditions more difficult. During the mining of coal is exposing rocks and gases contained in a fluid leak into the pavement, because there is less air pressure from the pressure of the gas contained in rock mass. The location of some of the gas sensors enforce mining regulations, but about the additional sensors determines ventilation engineer, who, on grounds of security ordered to mount sensors in areas where hazards may occur explosive or toxic gas. Huge role in minimizing the risks of gas plays an efficient and effective ventilation. In coal mines the most commonly used principal ventilators and air-duct used for ventilation of blind excavations [9, 10].

The system automatically operating air flow sensor, the concentration of methane and carbon monoxide respectively placed in excavations of ventilation flowing and distinct gives possibility of controlling the air in a manner that the relative safety of the crew of the mining.

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