ZDZISŁAW KRZYSTANEK
JERZY MRÓZ
STANISŁAW TRENCZEK

Integrated system for monitoring and analysis of methane hazards in the longwall area

Polish hard coal mines with high methane explosion hazards commonly use systems for automatic monitoring of air parameters. These systems are used by ventilation personnel in preventive actions, simulation tests and designs. The systems work independently and the measurement data, needed for ventilation calculations, are used only off-line and in a small extent. As a result of that, the calculations are conducted on obsolete data and their results are often far from reality. The European project AVENTO dealt with the integration of systems that enable to supply measurement data to calculation programs working in real time mode. The integration enables to observe on-line the changes in ventilation parameters and the level of methane explosion hazard. In addition, it allows to calculate the hazard indicators stipulated by valid regulations, along with the balance of methane which is drained along ventilation paths and pipelines of the degassing system. The paper reports also results of in situ tests of the integrated system.

Keywords: *methane hazard, ventilation, methane forecasting.*

1. INTRODUCTION

Natural hazards [22], particularly those which are related to ventilation [18], are the main source of risks for coal mining. The most dangerous one are methane explosion and coal dust explosion hazards [10], as well as spontaneous fire hazards [20, 22]. The seismic activity of the rock mass has a serious impact on the level of ventilation hazards [2, 11, 24]. In many Polish mines, seismic and ventilation-related hazards occur simultaneously and create a system of interacting associated hazards. In order to have safe and efficient mining exploitation, it is necessary to implement efficient prevention, i.e. early identification and dealing with hazards. Such operations, apart from good knowledge of the current state of the ventilation system, require the ability of predicting the level of hazards in a long [16] and short term [5, 18]. This way the adopted prevention actions can be more efficient and hazardous events can be avoided with higher probability.

In the Polish coal mining sector all natural hazards, their systematic monitoring and routine procedures of hazards assessment are described in the form of a law binding on all mines [29]. The level of ventilation hazards in mines is monitored by continuously developed monitoring systems [2, 8, 23, 27] which ensure on-line measurement of most important air parameters in excavations (air flow velocity, temperature, pressure, concentration of gases) and give signals whenever the accepted levels are exceeded. Programs to calculate ventilation parameters are used for assessing the risk resulting from hazards and while planning prevention actions by the mine personnel [6, 7, 21, 25]. These programs use off-line measurement data from monitoring systems. The data are supplemented by the results of manual measurements. However, the practice shows that the employed methodology does not bring satisfactory results. The basic reason is a particularly work- and time-consuming procedure to complete the measurement data. Thus all analyses and simulation tests related to risk assessment are made with certain delays and the presented data are often obsolete.

In order to get rid of these disadvantages, the AVENTO project was launched – Advanced Tools for Ventilation and Methane Emissions Control. The project was co-financed by the European Coal&Steel program. Its objective was to develop methods and tools that would allow to integrate environmental monitoring systems used in mines with a number of computer programs, either existing, improved or developed within the project to be used by ventilation personnel. These tools should enable them to analyze the mine ventilation system in operations related to on-line monitoring of the ventilation state, methane and fire prevention and in crisis situations. The main idea of the research was to improve simulation mechanisms of the ventilation network and to develop a reliable mechanism that would allow the ventilation analysis programs to access the data base of the environment monitoring system. The research made it possible to monitor the changing state of hazards and the parameters of the ventilation network in real time. The project assumptions, along with interim results of research, were consulted with the representatives of the ventilation personnel of mines for which the developed tools were intended.

The article features the results of works conducted in the EMAG Institute within the AVENTO project. The works were conducted in the following two aspects:

1. To modify the system for ventilation calculations and for monitoring the state of the ventilation network with a view to enable their co-operation in real time mode.
2. To implement methane balance functions which enable to asess the level of the methane hazard in longwall areas with respect to methane drainage efficiency.

The project included also the research works on short-term forecasts of methane hazard with use of machine inference. The results of the research works are a subject of a separate publication.

2. MINE ENVIRONMENT MONITORING AND VENTILATION CALCULATIONS IN POLISH MINES – STATE OF THE ART

2.1. Monitoring environmental parameters

Ventilation in Polish mines is monitored by different systems provided by different companies (EMAG, HASO, MICON, Carboautomatyka) [2]. Though these systems apply different technological solutions, their functional structures are, in fact, similar and comprise the following basic elements (Fig. 1):

- measuring sensors,
- transmission and power supply system,
- data archiving block,
- visualization and alarming block at the safety operator’s stand.

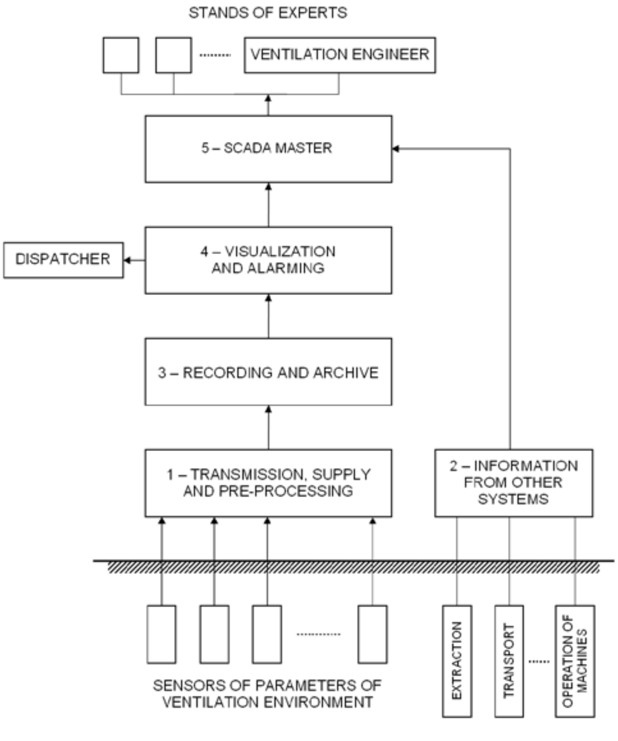


Fig 1. System for monitoring ventilation environment of a mine – functional diagram

The selected measurement data go to the operators' stands of the mine specialized departments. One of the most important departments that uses these data is the Ventilation Department.

Systems for monitoring methane hazards have the following basic functions:

- on-line measurement of methane concentration and other air parameters in excavations and pipelines of the methane drainage system;
- monitoring the state of ventilation equipment (air dams, fans) as well as selected machines and devices which are important in terms of safety;
- automatic switch-off of underground machines and devices when admissible values of methane concentration are exceeded;
- data visualization in the supervision stand, warning alarms when admissible values of the measured parameters are exceeded;
- archiving and reporting aboutmeasurement data and events.

An example of a system for monitoring environmental parameters is the SMP-NT system which has been developed and updated since 1990s. The system is now used in the majority of hard coal mines in Poland, it also operates in Ukraine and Belarus [14,23]. Its structure and principle of operation are presented in Fig. 2.

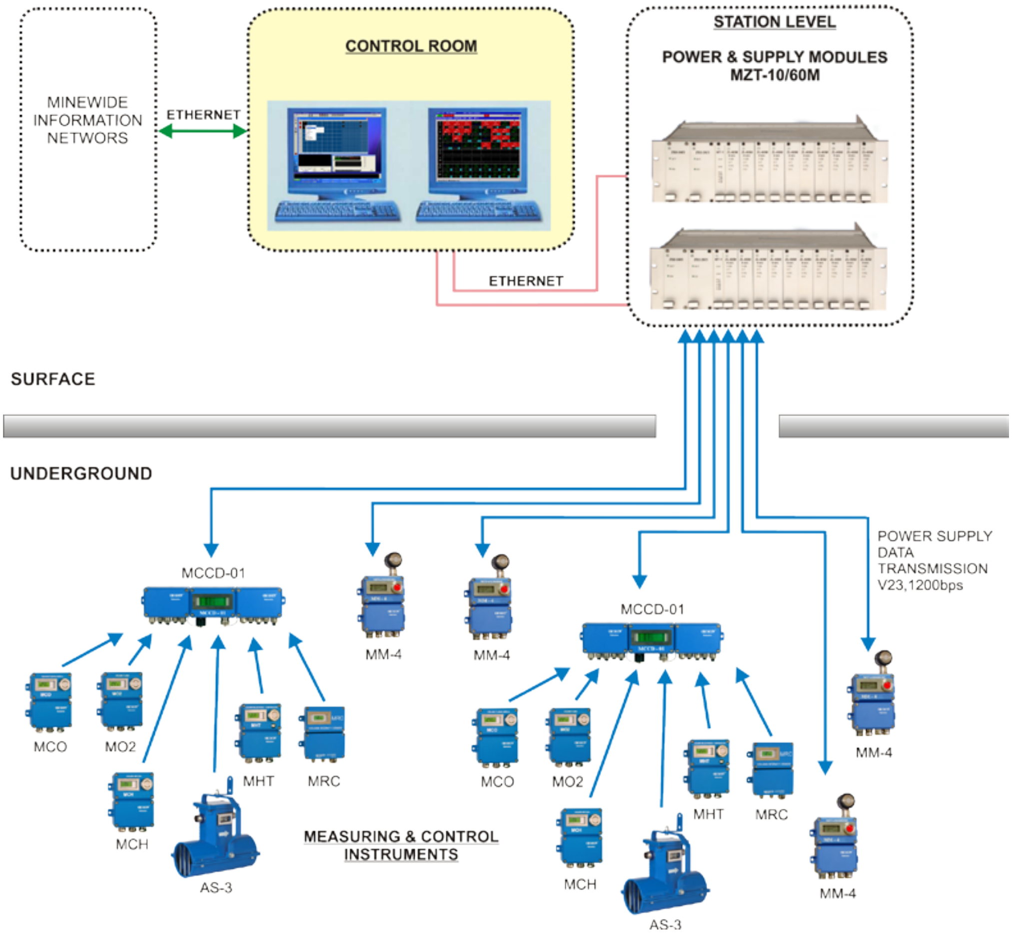


Fig. 2. SMP-NT system for monitoring environmental parameters

The SMP-NT system, just like similar systems offered by other companies, has a star-shaped arrangement of devices which allows remote supply of measuring devices from the surface. Such a solution has a clear advantage, i.e. the operations of the system are maintained in emergency and crisis situations when the underground electrical power grid is switched off, for example due to exceeded methane concentration values.

Most coal mines in Poland exploit coal beds with high methane content. Therefore methane sensors are the most numerous measuring devices under the ground. Other frequently used sensors are air- flow and carbon oxide sensors which are used in fire prevention. Air temperature and humidity sensors, carbon dioxide sensors and sensors for measuring gas impurities are slightly less common. Recently, absolute pressure meters have been installed more and more often in the nodes of ventilation networks. Their usage is very important from the point of view of accuracy and reliability in the calculation of air distribution.

Apart of analogue values, SMP-NT monitors the state of many bi-stable sensors (e.g. state of ventilation equipment). In addition, it can perform bi-stable control of devices which are used for automatic switch-off of machines and devices and can signal hazardous states. The states of all sensors, both analogue and bi-stable ones, are monitored and registered in the archives of SMP-NT, with the sampling period of two seconds.

2.2. Ventilation calculations

For calculation purposes the network is described by a model in the form of a graph with determined air-flow directions. The model is composed of N nodes and M edges (branches). The branches represent all kinds of ways along which the air can flow. The nodes are connections between the air-flow ways. Each branch has a parameter assigned – air resistance [15, 28] which represents the impact of friction that the flowing air has to overcome. The resulting pressure drops are overcome by ventilators which produce pressure whose value ensures the required air distribution. Apart of mechanical depression in branches, produced by the ventilators, natural depression is generated whose volume depends on the air temperature and position heads of the branch nodes.

In order to calculate air distribution in the mine ventilation network, a non-linear set of equations is used. The equations express the law of conservation of mass and energy, known as Kirchhoff's law. These are the following:

1. Nodal equations:

$$\sum_{i=1}^{N} b_{ki} \cdot q_i = 0 \quad [\mathrm{m^3/s}] \qquad k = 1,2,\ldots,P-1 \tag{1}$$

2. Loop equations:

$$\sum_{i=1}^{N} c_{ji} \cdot \left(H_i - R_i q_i^2 \operatorname{sgn} q\right) = 0 \quad [\mathrm{Pa}] \qquad j = 1,2,\ldots,M \tag{2}$$

where:

N – number of branches;
P – number of nodes;
$M = N - P + 1$ – cyclomatic complexity of the graph which maps the ventilation network;
b_{ki}, c_{ki} – elements of a nodal-branch matrix and a loop matrix which describe the topology of the ventilation network;
H_i – sum of natural and mechanical depression in the i-th branch;
R_i – air resistance of the i-th branch;
q_i – volumetric rate of airflow in the i-th branch.

The parameters of a model of a ventilation system have been changing in time and therefore such programs are activated at intervals in order to conclude if the conditions of a safe mining are still observed. Determining a new state requires a contribution to be prepared in a form of corrected parameters of the ventilation system to be made as a rule on the basis of measurements carried out by means of hand-held instruments and/or the measuring data of gasometric system loaded to the ventilation calculation system by off-line method. Thanks to integration of the ventilation model and the gasometric system, the model of the ventilation network can be corrected on an ongoing basis, extremely after all readouts of sensors of the gasometric system. Such a quasi-dynamic method allows us to obtain a record of the whole process of transition of the ventilation system from one state (the old one) to a new one (the current state).

Ventilation networks of today’s Polish mines have very complex structures. They consist of several hundred branches and nodes. Each change in this structure or in the network parameters requires to conduct air quantity measurements, update the model and recalculate the network. The majority of programs for ventilation calculations, employed to solve the equations of the model, make use of an iterative algorithm by Hardy Cross [3, 28].

There are a number of ventilation management programs that are used in Polish mines, for example: AERO (Silesian University of Technology and IFK company), Ventgraph (Strata Mechanics Research Institute of the Polish Academy of Sciences) and AutoWENT (Wrocław University of Technology) [27]. In the carried out research the AERO program was used. Contrary to other programs, it provides a complex approach to the calculation and documentation aspect, operates quickly, has a user-friendly interface, and is in compliance with Polish standards.

AERO is responsible for the management, calculation and balance of air distribution in the mine ventilation network. It enables to model changes, conduct simulations and document the network parameters. It co-operates with spatial schemes and canonical schemes of the mine in the AutoCAD environment. In emergency situations the program enables to identify hazardous zones with dangerous gases (e.g. CO, CH_4) and provides a list of endangered branches and observation points. It is also possible to have automatic calculation of the network based on the readings of sensors located in the hazardous zone.

The system comprises two basic modules – Standard Data Input Program and Graphical Module working in the AutoCAD environment. The basic element of the former module is a proper calculation program wchich solves the model (equations) by algorithms based on the above mentioned Hardy Cross method. The parameters which are indispensable for the program to work are entered into the following tabs:

- Nodes – spatial co-ordinates and air parameters in the nodes of the mine ventilation system,
- Fans – working parameters of fans; each of them has its own characteristics which can be edited and displayed in the form of a chart; in addition, it is possible to calculate the coefficients of the polynomial which determines the characteristics of the fan,
- Branches – recording the mathematical model of the mine ventilation system; the model defines the structure and parameters of ventilation connections between particular nodes.

The AERO interface is supplemented with a dedicated graphical editor which uses the data recorded in the numerical part and maps these data onto the frame of the spatial scheme. This way it is possible to view the structure of the mine (canonical and spatial scheme) in AutoCAD. With the use of a graphical editor it is also possible to modify the mine structure and change the parameters of the ventilation network. After the changes are made, the program recalculates the whole ventilation network and updates the values of displayed parameters on the scheme.

3. INTELLIGENT INTEGRATED MONITORING SYSTEM

3.1. System functions

A standard monitoring system (e.g. SMP-NT which we used) has a number of functions which are needed by the system administrator. However, the most important, basic function of the system is limited to measurements. A similar situation occurs with AERO. Based on the data obtained by the system, the administrator cannot monitor on-line the specific parameters of the ventilation network that impact the analysis and assessment of hazards, particularly the methane hazard.

SMP-NT and AERO, presented in the previous chapter, perform a number of tasks related to monitoring. To be more precise, SMP-NT enables on-line monitoring and visualization of currently measured quantities. AERO, in turn, presents a static scheme of the ventilation network after it is supplied with historical data. Therefore, in fact, the assessment of the methane hazard comes down to the following:

- ensuring automatic switch-off of current when critical values of methane concentration are exceeded on any sensor (SMP-NT),
- alarming when the values of any monitored parameter (e.g. anemometer, dam opening/closure sensor) are incorrect (SMP-NT),
- regular (usually conducted once every few days) analysis of gases and air distribution in the bed (AERO).

The integrated monitoring system, developed within the project, not only allows to supply the AERO system with the current data coming on-line, but also to provide two-way communication between SMP-NT and AERO. In addition, it exceeds the functionality of SMP-NT by the possibility to analyze trends and predict methane concentration values (as well as readings of any other sensors) by means of two computational intelligence methods [12, 17, 19]. Thus the developed system has the characteristics of both a measuring and IT system [1, 4].

3.2. System structure

The functional diagram of the new system is depicted in Fig. 3. In comparison with the structure from Fig. 2, the new one contains an extra program block (6) which is responsible for network-form calculations, methane balance analyses and short-term prognoses about the changes in the methane hazard status.

The block (6) is supplied on-line by measurement results from the sensors of the environment monitoring system by means of a central data base, developed during the research, and a communication protocol. In practice, it means that programs, which make up the analysis block, work all the time on updated and current data. The results of measurements and analyses, along with current measurement data, are basically intended for the mine ventilation personnel. They can also be used in the on-line mode to produce warning signals at the operator's stand.

3.3. Analysis block of the ventilation environment

The diagram of data flow in the integrated monitoring system is shown in Fig. 4.

The basis of the block operation is the integrated database. The objective of the base is to integrate and provide access to measurement data which come from different monitoring systems (particularly from

SMP-NT) The database is updated according to the sampling times of the environment monitoring systems. The data integration is based on assigning the data to a certain place in the mine (e.g. one excavation) and artificial unification of sampling time. The integration related to a place is based on the unification of the mine structure terminology and the places where sensors are installed, i.e. the places where the measurements come from. Thanks to a pre-defined set of dictionaries (defined while a successive system is connected to the data base) it is possible to unify the names of roads, excavations, etc., as they may often have different names and identification symbols in different systems. The artificial unification of the sampling time can be described with the following steps. One full measurement vector of the data base can be accessed from the outside. The vector contains all measurement results stored in the base. The vector is updated (and can be accessed) in compliance with the shortest sampling time. For example, if the given methane sensor (e.g. MM116) has the shortest sampling time (e.g. 2 seconds), then the cycle in which the vector can be accessed for further analysis is 2 seconds as well. Obviously, the measurements coming from sensors with longer sampling times will be changing in the accessed vector every few cycles.

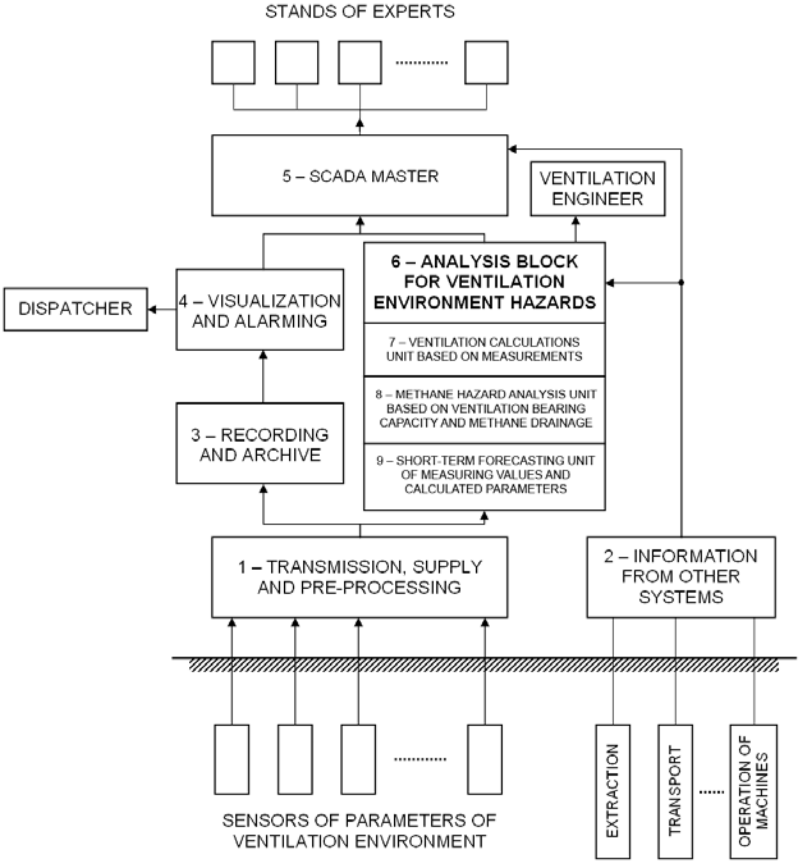


Fig. 3. Functional diagram of integrated system for environmental monitoring and ventilation calculation

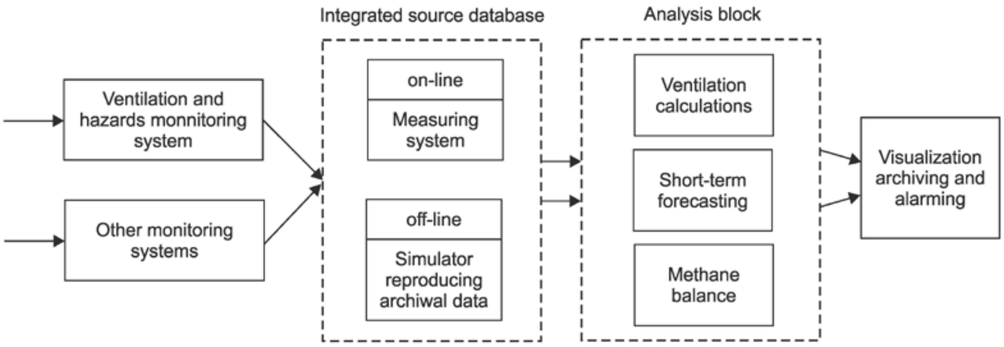


Fig. 4. Block diagram of software layer of the analysis block

Apart of on-line work, another method was employed to give access to source data. According to the method, databases are supplied with archived data once and then these data are recreated in simulation conditions. Thus it is not necessary to be connected on-line to the system working in the mine. This enables to recreate the courses of measured parameters, thus it provides a full-scale simulation of the real monitoring system operations, in compliance with the real changes in the object state parameters. This method was used during the research part of the project.

3.4. Ventilation network calculation module with on-line measurements

The main element of the module is a modified AERO program, including a configuration part, an editor and a graphical user interface. The package was supplemented to collect information directly from the integrated measurement data base. This feature ensured on-line up-date of the mathematical model of the mine ventilation structure in a real time.

To be more precise, the mathematical model is recalculated according to the time interval defined by the user. As the mathematical model is based on average measurement data, during the model recalculation the average values of the latest measurement data are taken into account. Thus the recalculation requires that values of two parameters should be given: the frequency of the model recalculation and the width of the measurement window wchich selects the values to be averaged.

During the research it was found out that in spite of a high degree of complexity in the modern mines ventilation networks, which comprise several hundred excavations, and in spite of time-consuming ventilation calculations, the applied integration mechanism and the proposed modifications to the AERO program enable to recalculate the whole network in a relatively short time of a few seconds. In practice, except of crisis situations, it is not necessary to recalculate the whole network that often. Therefore the integration mechanism gives a possibility to define time parameters of the module and the aggregation (averaging) method of data which are supplied to the ventilation calculations module.

Thanks to the use of an intermediary element, the data source for a new version of the AERO program can be any measurement system which supplies the integrated database.

3.5. Methane balance module for the longwall area

Mostly, methane can be found in mines in the longwall areas [13, 26]. Methane emitted from solid coal, broken and transported coal and from goafs is transported with the ventilation air to the upcast shaft. The mines which exploit coal beds with high methane concentration use an extra method of eliminating excess methane from the longwall area, i.e. they use methane drainage systems with drainage holes and pipelines which transport methane straight to the surface, omitting the ventilation system. Within the conducted research there was software developed which enabled to determine the current volume of gas emitted in the longwall area on the basis of the data (provided by the integrated database) about methane concentration, air velocity in excavations and parameters of the air-methane mixture in the methane drainage pipelines.

In order to determine methane-bearing capacity, i.e. the volume of methane emitted in the area, the mining industry in Poland applies a method developed in the Experimental Mine Barbara [13]. The method uses the averaged values of methane concentration and air velocity for calculations. The methane-bearing capacity of the longwall area is characterized by the following:

1. Ventilation methane-bearing capacity (M_{VM}) – difference between the volume of pure methane measured in the outflow air current and the volume of methane that flows into the longwall area.
2. Absolute methane-bearing capacity – total volume of methane emitted to the ventilation air and the methane drained by the pipelines of the methane drainage system.
3. Criterial methane-bearing capacity (M_{CM}) – maximum absolute methane-bearing capacity which takes into account uneven emission of methane at which the admissible values of methane concentration in the return air current are not exceeded.

Based on the above it is possible to determine the following parameters. Absolute criterial methane-bearing capacity is the maximum value of absolute methane-bearing capacity for the given ventilation conditions and for the methane-drainage efficiency at which methane content in the used air flow does not exceed the admissible value. The adopted measurement unit is m^3/min. The efficiency of methane drainage is the percentage of drained methane, calculated in relation to absolute methane-bearing capacity. The developed software compares the value of ventilation methane-bearing capacity with the value of M_{CM} and the methane-drainage efficiency with the efficiency assumed in the design of the longwall. Methane hazard assessment is carried out based on the methane hazard indicator k_H (3) and the indicator of the methane-drainage efficiency k_E (4). Methane hazard levels are determined in compliance with Tables 1 and 2.

$$k_H = \frac{M_{VM}}{M_{CM}} \tag{3}$$

where:
M_{VM} – ventilation methane-bearing capacity [m^3/min],
M_{CM} – criterial methane-bearing capacity [m^3/min].

$$k_E = \frac{E_{DE}}{E} \tag{4}$$

where:
E_{DE} – calculated methane-drainage efficiency [%],
E – assumed methane-drainage efficiency [%].

Table 1.

Degrees of methane hazard calculated depending on the value of k_H indicator

k_H	Degree of methane hazard
≥ 1,0	Dangerous longwall, very high methane hazard
[0.8 ; 1.0)	High methane hazard
[0.5 ; 0.8)	Moderate methane hazard
[0.2 ; 0.5)	Low methane hazard
< 0.2	No hazard

Table 2.

Degrees of methane hazard calculated depending on the value of k_E indicator

k_E	Degree of methane-drainage efficiency
≥ 0.5	High methane-drainage efficiency
[0.3 ; 0.5)	Medium methane-drainage efficiency
< 0.3	Low methane-drainage efficiency

Depending on the achieved indicators, decisions are made to reduce the methane hazard to the admissible level (by regulating the ventilation network, reducing the mining speed, increasing the methane-drainage efficiency, etc.).

4. SELECTED RESULTS OF THE INTEGRATED SYSTEM TESTS

4.1. Calculating the ventilation network after changes in air flow

The tests of the ventilation network parameters were conducted on the basis of measurement data registered during a ventilation experiment in the N-2 longwall area. The diagram of the longwall, made with the use of the AERO program, is presented Fig. 5. The objective of the tests was to confirm the accuracy of the mechanism which integrates monitoring systems and ventilation calculations. Particularly, it was intended to check whether is it possible to fulfill time conditions necessary for the systems to co-operate in real time in the conditions of significant air distribution changes.

The N-2 longwall was ventilated with the use of the Y method by means of the main fresh air stream flowing along the N-2 road and an auxiliary stream supplied to the face end along the N-3 road. The air distribution in the area was regulated by air dams T1, T2, T3 and T4. In the normal state, before the experiment began, the T1 dam was open while the remaining dams were closed.

The area was equipped with a standard set of stationary measuring devices which were in compliance with valid regulations. For the time of the experiment, this set was supplemented with extra sensors, i.e. absolute pressure and air velocity sensors, which were installed in the excavations (inlet, outlet, fresh air supply). Additionally, a methane drainage parameters sensor was installed in the main pipeline that transports methane from the rock mass and goafs.

Due to security reasons, the experiment was conducted when no mining operations were under way. The idea of the experiment was to invoke some ventilation disturbances in the area by means of changing the locations of the dams T1 and T3. The experiment comprised the following stages:

1. State I (starting point) – T1 open, T3 closed.
2. State II (less air supplied to the area) – T1, T3 closed.
3. Return to the starting point.
4. State III (change in the proportion of air streams supplied to the longwall) – T1, T3 open.
5. Return to the starting point.

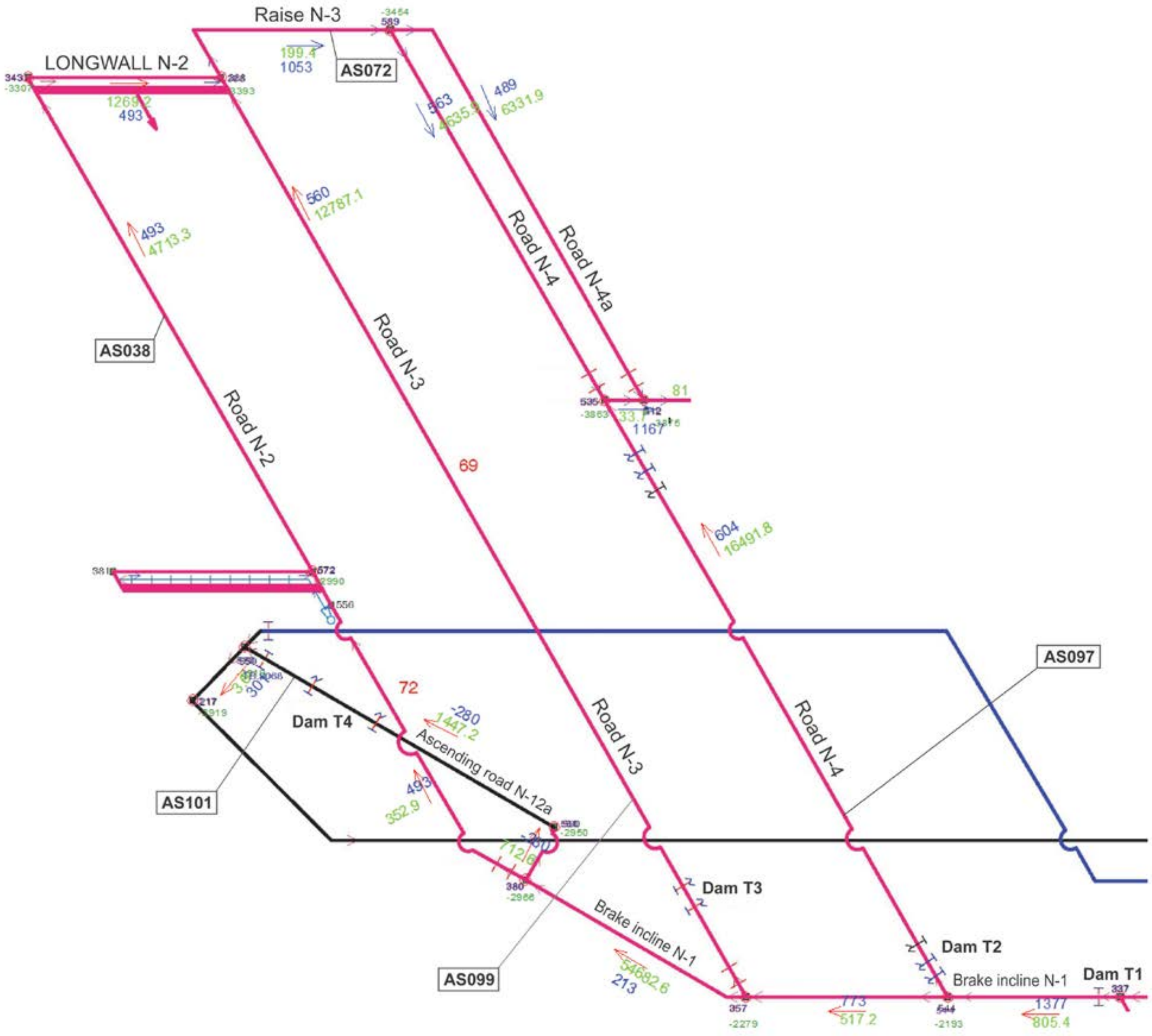


Fig. 5. N-2 longwall area during the ventilation experiment

Before and during the experiment there were some air flow measurements made manually in several important spots of the area.

The closing of the T1 dam (State I) resulted in significant changes in air output in the excavations of the area. In addition, the air current got reversed in the N-12a uphill drift due to self-opening of T4, while the air flowed through N-12a to the N-1 incline. This fact was confirmed by measurements conducted with a portable anemometer. The invoked changes were accompanied by transitional states with a significant amplitude and duration. Figure 6 features the waveforms of air velocity registered during the experiment.

The actual research works were carried out in a computer laboratory with use of an archive of a mining monitoring system which served – as shown in Fig. 3 – as a source data base for simulation of real courses by means of a program which was especially designed for this purpose. The program loaded successive archived data with a sampling period of 2 seconds, identically as has been used in the mining system. The results confirmed correctness of the solution which was developed within the scope of the project.

Table 3 features averaged values of air flow in most important branches of the area, calculated by the AERO program for the initial state and during regulating operations. In the analyzed case, the recalculation of the ventilation network was carried out just in 4 seconds. This time is enough even when it is necessary to conduct simulations during rescue operations.

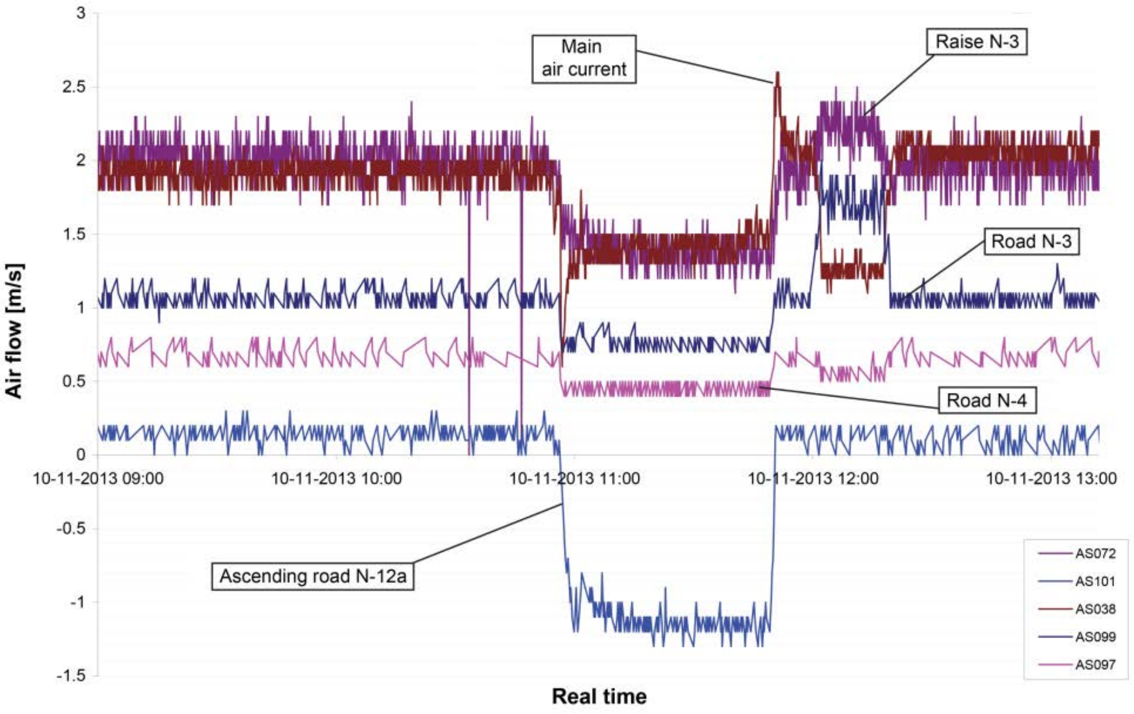


Fig. 6. Air flow velocity in the N-2 longwall area during ventilation changes

Table 3.

Air output in selected branches of the N-2 longwall area

Branches	Characteristics	State I T1 open T3 closed [m^3/min]	State II T1, T3 closed [m^3/min]	State III T1 open T3 closed [m^3/min]
1	2	3	4	5
337-544	Flow into the area	3237	1377	3127
544-357		2297	773	2160
544-535		940	604	967
380-343	Supply stream	1153	493	564
343-388	Excavation	1153	493	564
357-388	Fresh air supply	970	560	1142
380-550	Lateral current	173	-280	454
388-589	Face end	2123	1053	1706
589-535	Flows out of the longwall	876	563	928
589-512		1248	489	778

4.2. Simulation of methane distribution in places with higher methane concentration

Simulations of a significant impact of methane emission in a longwall face and observation of a flow way of gas along the workings of the ventilation system have been the one of elements of the research works. The effect has been obtained by introducing a virtual source of methane emission into a longwall face, which caused increasing in CH4 concentration up to 10%.

After the simulation was launched, the program, in a time imperceptible to the user, generated a hazardous zone, i.e. identified the path of the mixture with increased methane content from the place where it flows into the upcast shaft (yellow color) and marked the locations of the so called observation spots (methane sensors) (Fig. 7) marked with the letter P. The endangered branches and observing methane sensors are marked automatically with a different colour. At the arrows showing a flow direction the program gives the values of the air flow volume and percentage values of methane concentration (green colour). In the integrated system the simulation is activated automatically by a methane sensor located at the longwall face area when the allowable values of methane concentration are exceeded. Similar simulations can be conducted for other gases, e.g. CO, CO_2, smoke.

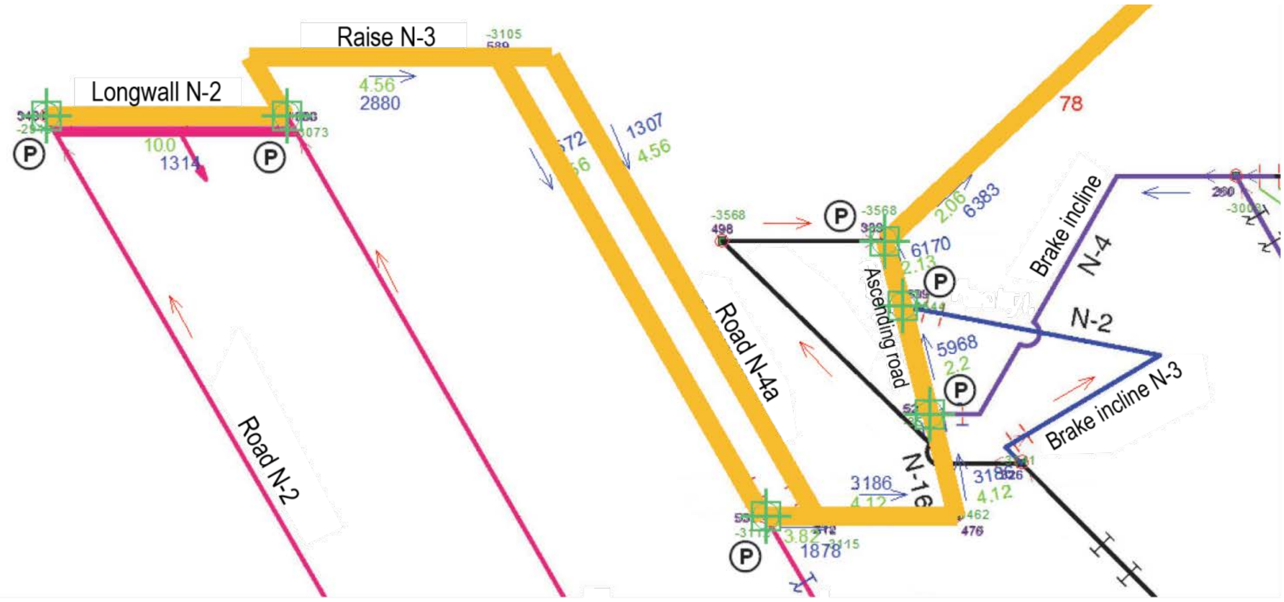
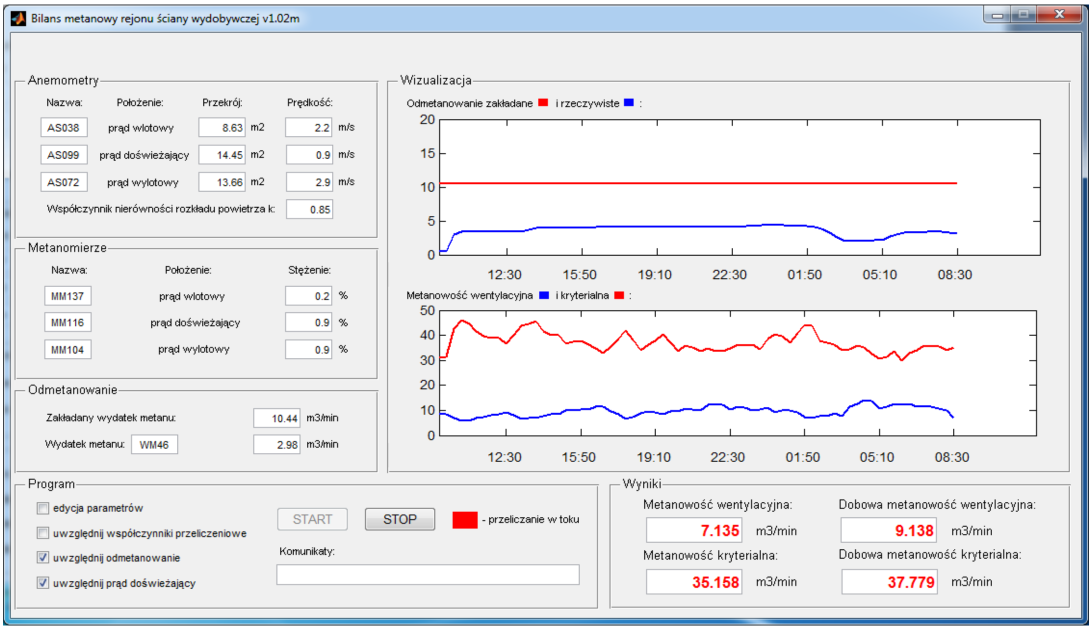


Fig. 7. Simulation of methane outflow in the N-2 longwall (red arrows mean fresh air)

4.3. Determining coefficients of methane-bearing capacity in the longwall area

Within the conducted research there were some procedures implemented to calculate the coefficients of methane-bearing capacity on the basis of current values of sensor readings.

Figure 8 features a window of this part of the application which is responsible for determining methane-bearing capacity coefficients of the longwall area. The values of the coefficients can be calculated on-line or on the operator's demand.


Bilans metanowy rejonu ściany wydobywczej v1.02m

Anemometry

Nazwa:	Położenie:	Przekrój:	Prędkość:
AS038	prąd wlotowy	8.63 m2	2.2 m/s
AS099	prąd doświeżający	14.45 m2	0.9 m/s
AS072	prąd wylotowy	13.66 m2	2.9 m/s

Współczynnik nierówności rozkładu powietrza k: 0.85

Metanomierze

Nazwa:	Położenie:	Stężenie:
MM137	prąd wlotowy	0.2 %
MM116	prąd doświeżający	0.9 %
MM104	prąd wylotowy	0.9 %

Odmetanowanie

Zakładany wydatek metanu: 10.44 m3/min

Wydatek metanu: WM46 2.98 m3/min

Program

☐ edycja parametrów

☐ uwzględnij współczynniki przeliczeniowe

☑ uwzględnij odmetanowanie

☑ uwzględnij prąd doświeżający

🟥 - przeliczanie w toku

Komunikaty:

Wyniki

Metanowość wentylacyjna: 7.135 m3/min

Dobowa metanowość wentylacyjna: 9.138 m3/min

Metanowość kryterialna: 35.158 m3/min

Dobowa metanowość kryterialna: 37.779 m3/min

Fig. 8. Window featuring methane-bearing capacity balance of the longwall area

The left side of the window contains current readings of sensors based on which the calculations are done. The right side presents daily charts of the assumed and real efficiency of methane drainage (upper chart) as well as ventilation methane-bearing capacity (M_{VM}) and criterial methane-bearing capacity (M_{CM}) – lower chart.

In the right bottom part of the window the program gives current and daily values of M_{VM} and M_{CM}. On this basis the values of the indicators (3) and (4) are calculated in accordance with Tables 1 and 2. Information about the values of (3) and (4) can be returned on-line to the SMP-NT system or any other supervision system.

5. CONCLUSIONS

In order to carry out complex assessment of the ventilation state and methane hazard in the longwall area it was necessary to develop new calculation procedures or modify the existing ones, including:

- calculating current changes in the ventilation network parameters based on the measurements of pressure changes and air velocity changes in branches,
- calculating, in real time, the flow of methane from the source to the upcast shaft based on the readings of the methane sensor installed near the source,
- assessing methane hazards – based on the on-line analysis of the ventilation methane-bearing capacity, criterial methane-bearing capacity and the efficiency of methane drainage with the use of measurement results from the sensors measuring air velocity, methane concentration and methane drainage parameters.

The results of the conducted tests confirmed the accuracy of the new intelligent integrated system for monitoring and analyses of the methane hazard. The developed system significantly extends the functionality of the existing solutions. At present there are actions undertaken to extend the methane monitoring systems in Poland by the functions presented in this article. In addition, some Chinese coal mines are showing interest in the developed solution.

References

1. Bilewicz K.: *Smart metering – Inteligentny system pomiarowy (Smart metering – an intelligent measurement system)*, Wydawnictwo Naukowe PWN, Warszawa 2011.
2. Cierpisz S., Miśkiewicz K., Wojaczek A.: *Systemy gazometryczne w górnictwie (Gas measurement systems in mining)*, Wydawnictwo Politechniki Śląskiej, Gliwice 2007.
3. Cross H.: *Analysis of flow in networks of conduits or conductors*, University of Illinois. Engineering Experiment Station. Bulletin; no. 286 1936.
4. Cuzzocrea A.: *Design, implementation and validation of AI-inspired information systems*, Journal if Intelligent Information Systems 45, pp.1-3 2015.
5. Dixon W.D.: *A Statistical Analysis of Monitored Data for Methane Prediction*, Extended Abstract of PhD Dissertation, University of Nottingham, Dept. of Mining Engineering, 1992.
6. Dziurzyński W., Pałka T.: *Symulacja komputerowa procesu przewietrzania kopalni z wykorzystaniem danych monitoringu (Computer simulation of mine ventilation process with the use of monitoring data)*, Materiały Szkoły Aerologii Górniczej. Wydawnictwo ITI EMAG, Katowice 2004, p. 77.
7. Dziurzyński W., Wasilewski S.: *Ocena zagrożenia metanowego w rejonie ściany na podstawie czujników gazometrii oraz symulacji komputerowej przepływu mieszaniny powietrza i metanu (Assessment of methane hazard in the longwall area based on gas-measuring sensors and computer simulation of air-methane mixture flow)*, Przegląd Górniczy 12, 2012, p. 28.
8. Gillies A.D.S, Wu H.W., Tuffs N., Sartor T.: *Development of a Real Time Airflow Monitoring and Control System*, Proceedings of the 10th US/North American Mine Ventilation Symposium, Anchorage, Alaska, USA, May 2004.
9. Hartman HL., Mutmansky J.M., Ramani R.V., Wang Y.J: *Mine ventilation and air conditioning*, New York: Wiley, 1997.
10. Kissel F.N: *Handbook for Dust Control in Mining*, National Institute for Occupational Safety and Health. Pittsburg PA, USA 2003.
11. Konopko W., Kabiesz J., Cygankiewicz J.: *Wstrząsy i tąpania jako inicjatory zagrożenia metanowego (Rock bursts as underlying factors of methane hazards)*, Przegląd Górniczy 2, 1994, pp. 29-34.
12. Kozielski M., Skowron A., Wróbel Ł., Sikora M.: *Regression rule learning for methane forecasting in coal mines*, International Conference – Beyond Databases Architectures and Structures. Communications in Computer and Information Science 521, Springer 2015, pp.495-504.
13. Krause E., Łukowicz K.: *Zasady prowadzenia ścian w warunkach zagrożenia metanowego. Instrukcja Nr 17 (Regulations of longwalls management in the conditions of methane hazard. Instruction No 17 Central Mining Institute)*, Główny Instytut Górnictwa, Mikołów 2004.
14. Krzystanek Z., Dylong A., Wojtas P.: *Monitorowanie parametrów środowiska w kopalniach węgla kamiennego – System SMP-NT (Monitoring of Environmental Parameters in Coal Mine The SMP-NT System)*, Mechanizacja i Automatyzacja Górnictwa 9, 2004, pp. 23-45.
15. McPherson, M. J.: *Subsurface ventilation and environmental engineering*, Springer Science & Business Media 2012.
16. Noack K.: *Control of Gas Emission in Underground Coal Mines*, International Journal of Coal Geology 35, 1998, pp. 57-82.
17. Sikora M., Sikora B.: *Improving prediction models applied in systems monitoring natural hazards and machinery*, International Journal of Applied Mathematics and Computer Science 2(22) 2012, pp. 477-491.
18. Sikora M., Krzystanek Z., Bojko B., Śpiechowicz K.: *Application of a hybrid method of machine learning for description and on-line estimation of methane hazard in mine workings*, Journal of Mining Sciences (4)47, 2011 pp.493-505.
19. Sikora M., Krzystanek Z., Bojko B., and Spiechowicz K.: *Hybrid Adaptative System of Gas Concentration Prediction in Hard-Coal Mines*, Proc. of the 19th Int. Conf. on Systems Engineering, IEEE Computer Society (CPS), 2008, Las Vegas, Nevada, USA
20. Stracher G.B., Praksh A., Sokol E.V (eds.): *Coal and peat fires*, A Global Perspective. Case studies – Coal fires. Elsevier 2015.
21. Szlązak J., Szlązak N., Borowski M. Obracaj D.: *Program komputerowy do obliczania rozkładu prędkości powietrza i stężenia metanu w zrobach ścian zawałowych (Computer program for calculating the distribution of air velocity and methane concentration in goafs)*, Materiały Szkoły Eksploatacji Podziemnej 97. Polska Akademia Nauk, Kraków 2006, p. 671.
22. Trenczek S.: *Charakterystyka zagrożeń naturalnych (Characteristics of natural hazards). Monitorowanie, telemetria i narzędzia informatyczne w górnictwie dla poprawy bezpieczeństwa pracy – wybrane zagadnienia (Monitoring, telemetry and IT tools in mining to improve work safety – selected issues)*, S. Trenczek (Ed.) Wydawnictwo ITI EMAG, Katowice 2014, pp. 7-29.
23. Trenczek S., Wojtas P.: *Rozwój monitorowania zagrożeń naturalnych w okresie ostatniego 20-lecia (Development in natural hazards monitoring during the last 20 years)*, Bezpieczeństwo Pracy i Ochrona Środowiska w Górnictwie 9, 2014, pp. 3-10.
24. Ulrey J.P.: *Explosion hazards from methane emissions related to geologic features in coal mines*, National Institute for Occupational Safety and Health. Pittsburg PA, USA 2008.
25. von Glehn, F.H., Ox, I.: *Monitoring and control of underground ventilation systems Rusing VUMA network*, Proceedings of the 10th US/North American Mine Ventilation Symposium, Anchorage, Alaska, USA, May 2004.
26. Vigil A.A, Nicieza C.G., Rodriguez M.A., Mendez A.: *Modelization of methane development in vertical coal seam exploited by sublevel stopping method*, International Journal of Surface Mining, Reclamation and Environment 10(1) 1996, pp.31-40.
27. Wasilewski S.: Automatic gas measurement. *Innowacje dla gospodarki (Innovations for the economy)*, S. Trenczek (Ed.), Wydawnictwo ITI EMAG, Katowice 2010, pp. 141–161.
28. Wacławik J., Roszczynialski W.: *Aerologia górnicza (Mining ventilation)*, Wydawnictwo Naukowe PWN, Warszawa 1983.
29. Rozporządzenie Ministra Środowiska z dnia 29 stycznia 2013 r. w sprawie zagrożeń naturalnych w zakładach górniczych. Dziennik Ustaw Rzeczypospolitej Polskiej 2013 poz. 230. (Decree by the Minister of the Environment from 29 January 2014 on natural hazards in mines, Journal of Law 2013, item 230.)

ZDZISŁAW KRZYSTANEK, Ph.D.
JERZY MRÓZ, Ph.D.
STANISŁAW TRENCZEK, Ph.D., D.Sc.
Institute of Innovative Technologies EMAG
Leopolda 31, 40-189, Katowice, Poland
{zdzislaw.krzystanek, jerzy.mroz,
stanislaw.treczek}@ibemag.pl