# Expert System for Mine Supervising Staff Fire Hazard Monitoring and Fire - Fighting

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## ABSTRACT

The paper presents the functions of an expert system designed for mine supervising staff responsible for fire hazard monitoring and fire-fighting. The essence of the system is to gather the complete data from hazard monitoring systems and the results of manual measurements made by ventilation staff in a common database. The database can be used for analysis and engineering calculation employed in mine ventilation supervision and also for the prevention against natural hazards, in particular fire and methane. Hardware and software tools developed within the framework of the system will also be used during rescue operation.

## KEYWORDS

Ventilation, Expert System, Fire Hazard, Fire-Fighting, Monitoring and Control Systems, and Computer Applications.

## INTRODUCTION

The computer-based systems of ventilation control and monitoring (methane and fire detection) are designed for the on-line monitoring of hazards. The users of these systems are the mine dispatchers and most functions of the systems are performed to match safety regulations and the needs of these services. The expert system objectives presented here significantly exceed the basic dispatching functions performed by the systems for hazard monitoring and ventilation control.

The basic responsibility for the ventilation staff is based on the "settled" (or normal) ventilation conditions, and its success depends on the reliability of data. The hazard monitoring systems deliver a large amount of measuring data to the surface where they are used for quantity control. Assisted by more sophisticated methods of data processing, the expert system can use current and archived data to enhance ventilation planning.

Additional ventilation surveys are carried out in mine workings by manual measurements in conformity with safety regulations. In addition to stationary sensors, manual measurements with different sampling periods are also used. The expert system can create direct access to programs enabling various processing and presentation of data to be collected in an integrated database from the monitoring systems and manual measurements.

Integrating VENTGRAPH opens new possibilities for data base and system interpretation. The system enables computer simulation of emergency and preventive actions for an underground fire and for making optimal decisions. The graphical presentation of the results on the mine schematic diagram can provide rapid verification of the calculation results by comparing with the actual data.

Such a tool can better facilitate preventive action and mine rescue operation, better decision making, and fire-fighting techniques.

## SYSTEMS USED FOR MINE VENTILATION CONTROL

### The Hazard Monitoring Systems

At present, mines use a new generation of computer based and continuous operation monitoring systems for methane and fire hazard detection, (Mironowicz and Wasilewski, 1997), or an old analogue station, OLDHAM CTT63/40Up and CMM20, with cyclic operation and 4 -minute sampling frequency. They deliver a large amount of data to the surface. In principle, these data are only used for monitoring of hazards. This accumulated an enormous database which operation has not been used fully due to lack of suitable programs.

### ZEFIR - Supervising and Management System

At present in Polish mines the supervising and management system called ZEFIR is the standard within a computer-based dispatching system which collects in one location the measuring data from different sources of both analogue and binary signals; this system enables:

- monitoring of the ventilation equipment operation as well as production and transport operation,
- data acquisition and co-operation with the autonomous hazard control system in mines, among them with:
  * OLDHAM CTT63/40Up and CMM20 (analogue), or (digital) type CMC-1/2-methanometric stations,
  * SMP computer - based continuous methane and fire hazard monitoring systems,
  * VENTURON computer - based production and safety control systems,
- archived ventilation data with alarming capacity,
- mine computer network for supervising and coal mine production safety.

The system provides data recording and observation of current and archived measuring data but only in a day cycle. It does not permit analysis in different profiles and time horizons or engineering calculation. Making use of data for special processing for the purpose of analytical calculation and prevention made by the ventilation staff requires the development of suitable software.

Periodical Measurements by Manual Instruments

The complex estimation of ventilation parameters made based on current and archived data from the monitoring system also requires the data manually collected by the groups of surveyors and supervising staff.

Although the latest regulations permit computer based data recording and processing, it is rarely used due to the lack of a suitable program. Besides, separately recorded data from manual measurements should also be integrated into the database.

**VENTGRAPH System for Analysis and Simulation of Mine Ventilation.** The VENTGRAPH system is designed for the simulations and analysis of mine ventilation networks (Trutwin, *et al.*, 1997) and graphical presentation of the results on a schematic diagram. The system has mechanisms to assist to making decisions, and in particular it provides:

- analysis and calculation of mine ventilation network,
- variant calculation in order to make an optimal decision,
- computer simulation of emergency and preventive actions concerning underground fire,
- withdrawal of miners from endangered areas,
- simulation of fire expansion,
- indication of smokiness and hazard areas,
- simulation of passive (e.g., by means of stopping) or active preventive actions (e.g., by means of the inert gas generator type GAG),
- computer simulation of different exploitation and ventilation systems in the presence of for example a methane hazard and the effectiveness of control measures such as the use of methane drainage.

**Air Analysis Made in Gas Laboratory.** The Polish mine regulations concerning the early fire detection requires, as yet, very complicated procedures for recording measurments and gas analysis results. Both data measuring and gas analyses, made in a mine gas laboratory, must be inscribed separately for each measuring station, in a special form to a Mine Ventilation Book. The book is submitted every day to:

- Main Ventilation Engineer,
- Leading Mine Engineer.

Such a collection of documents and inspection of analyses and their delivery from laboratory to the users may be simplified by a mine computer network. Linking the computer network with the three interested divisions, i.e., gas laboratory, ventilation department and mine dispatch room (operation headquarter), will produce conditions for:

- transfer of analyses to all interested parties,
- observation of changes in air composition, in a form of tables and diagrams,
- fast and easy access to the results of gas analysis by ventilation service and operation staff.

Especially during fire situations, the immediate access to measuring data and gas analysis results is critical to an efficient rescue operation. The new methods for recording measuring data, results evidence and the algorithms of index calculation as well as printouts and diagrams sizes must be agreed upon by both the users and the mining authorities.

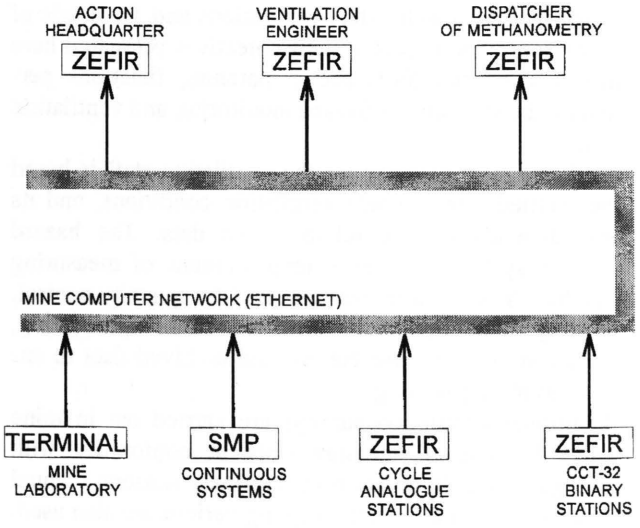


*Figure 1. Scheme of the expert system for mine supervising staff.*

## THE EXPERT SYSTEM FOR MINE VENTILATION SUPERVISING STAFF

The systems presently used for ventilation monitoring are entirely separate stations and up to now there has been no possibility to join them. The expert system (Dziurzynski *e,t al.*, 1997) integrates these systems (Figure 1) and makes available current and archived data of the ventilation process and permits their wide use in ventilation service work. Making these new software tools accessible to mines will also improve the preventative actions and rescue operation, especially in case of fire. Thus the expert system will contribute to the optimization of performed work in regard to its correctness and use of really necessary means.

### Integrated Ventilation Data Base

In the expert system all the information on air parameters both from automatic sensors in monitoring systems and those taken with by manual instruments at measuring stations are available. The common databases (Figure 2) can contribute to wide use of all data on ventilation processes condition in preventive actions carried out by mine ventilation staff. Information collected in the database can also support engineering programs used by ventilation departments in mines. New software such as the expert system makes the access to data easy and creates the tools for the manual and automatic measurements results in a form of computer record with the possibility of a periodical printouts or on request. The availability of such data in emergency states would permit the most effective operation by mine staff.

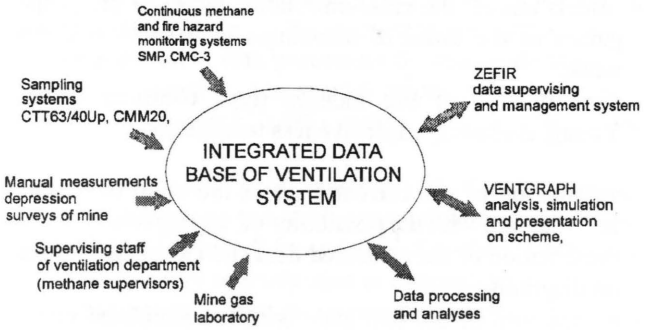


*Figure 2. Integrated ventilation database.*

### The Main Function of the Expert System

The system provides real assistance to mine service personnel with protection, analysis and calculation of mine ventilation network (Figure 3). The basic functions of system can be characterized as follows:

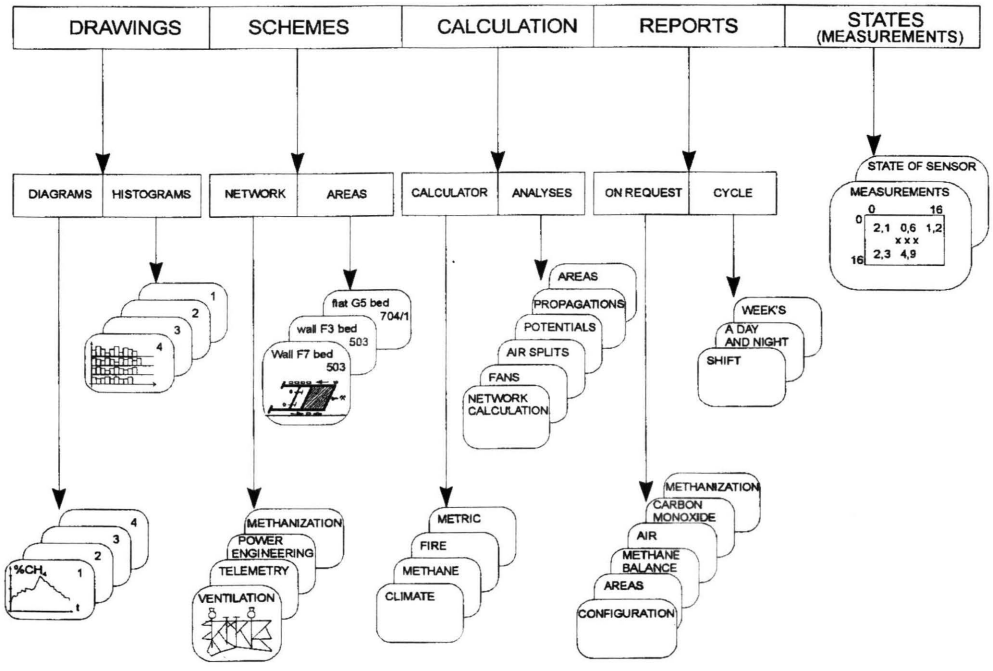


*Figure 3. The main functions of the expert system.*

1. Special processing of output signals from the sensors in the hazard monitoring systems, namely:
   - filtering out disturbances,
   - determination of signals and expected hazard times,
   - creation of statistics of signals parameters.

2. Calculation of indexes and criteria to estimate the yeild of gas sources and degree of danger, namely:
   - measurement and calculation of gas quantities (CO, $CH_4$) emitted in production areas,
   - determination of gas source characteristics,
   - calculation of the cross-correlation tables of gas propagation as the times of smokiness in a ventilation network,
   - determination of fire indexes (type Graham, Tricket, Young, Bystron), explosiveness triangle etc.

3. Presentation of the current state of the mine on a schematic diagram with the possibility of, among others:
   - presentation of the measured data and calculated indexes on diagrams,
   - comparison of the real state with the simulated one at any point of network,
   - observation of real gas distribution in ventilation network.

4. Balance and creation of specifications for different periods e.g., week, month. year, in this:
   - balance of methane in ventilation system and methane drainage,
   - determination of real methane quantity,
   - forecasting of gas emission,

5. Analysis and calculation of air propagation in ventilation network:
   - calculation of current state,
   - variant calculation,
   - simulation of abnormal and emergency states,
   - simulation of prevention actions and effectiveness of different ventilation systems and auxiliary equipment.

6. Engineering calculations, such as:
   - design of separate ventilation for mine workings,
   - forecasting of temperature and climatic conditions at mine workings.

## ASSISTANCE TO FIRE-FIGHTING OPERATIONS

Spontaneous combustion of coal and mine fires present serious safety hazards, so the early detection of a fire and prevention of it are the most important duties of mine ventilation staff. During a fire, the staff survival, duration and costs of action depend mainly on a degree of mine preparation for rescue operation. Therefore, particular emphasis is put into the level of mine readiness to manage the operation.

This includes, among other things, a degree of staff readiness, timeliness of fire-fighting plans, availability of the necessary tools and equipment at the early stage. The most effective means in a mine rescue operation, is a fast report of fire-fighting plans, correct location of fire, establishing the hazard areas, preventing posts and emergency telephones. It is also important to determine the number and location of the miners in danger zone and be knowledgeable of escape routes and the current mine plans of fire-fighting.

### Assistance to A Dispatcher during Staff Evacuation

At the first stage of a fire-fighting operation, a dispatcher concentrates on rescuing the staff and their evacuation from the danger zone. In the expert system, the dispatcher, after locating the fire and the miners, has an opportunity to look through the schemes of fire-fighting plans, stored in the master computer memory by calling the following panels:
- ZONE—danger zone,
- POSTS—layout of protective posts,
- INSTRUCTIONS—instructions for staff evacuation,
- TELEPHONE—list of emergency telephone numbers on the zone scheme.

For the controlled mine areas the respective fragments of mine fire-fighting plans have been stored in the computer memory. These are: danger zones (Figure 4), protective posts, instructions for staff evacuation and emergency telephone location. The dispatcher calls the required panels depending on fire location (Wasilewski 1995). He can also estimate ventilation condition in danger area on the schematic by checking air parameters, smoke and fire gases propagation. Owing to internal power supply of underground equipment (Mironowicz and Wasilew-ski, 1997), hazard monitoring system type SMP measurements will continue even after electricity is cut off. Hence, the monitoring of fire spread and effectiveness of fire fighting is possible even when sensors would be in zone with stopping, but of course only up to the time of measuring lines and sensors damage.

### Assistance to Ventilation Service and Action Headquarters During Fire-Fighting

Development of the monitoring-measuring systems and software allows the develop the present solution (Dziurzynski, *et al.*, 1997) by a stage of fire-fighting. Information on process condition is currently available in a mine ventilation department and in command headquarters. The data are completed in an integrated database by the actual results of gas analysis made in a mine laboratory. The mine staff and action headquarters have easy access to data and possibility of fast estimation of safety in a mine as a whole and in individual areas on the mine schematic displayed on large screen, as well as on monitor. During fire-fighting operation, the VENTGRAPH system software provides current computer simulation and variable calculation. It also uses the program package including analysis and mine ventilation network simulation for emergency, the duties of fire simulation for different means of its suppression e.g., passive by

stopping or active by using extinguishing equipment. The simulation results are currently verified by the coming-from-below data of mine air condition and are displayed on a common schematic diagram. Integration of information about mine safety within the framework of the expert system allows complex management and to apply effective prevention methods.

## SPECIAL DATA PROCESSING

The system is designed to assist mine staff in actions connected with prevention and analysis and calculation of mine ventilation system. The basic system functions (Figure 3) require the special processing of output signals from sensors (Wasilewski and Szywacz 1996). These include : filtration of disturbances, determination of trends of signals and expected hazard times changes, creation of statistics i.e. signals statistic parameters and determination of indices and criteria to estimate gas source emission and the extent of hazard. Performance of these functions requires access to current and archived data, which is supported by procedures and mechanisms of the supervising and management system ZEFIR.

### Special Processing of Data from Monitoring Systems

Access to the ZEFIR supervising and management system data collected in the monitoring systems of continuous operation, type SMP or cyclic methanometric systems makes the comprehensive data processing for the needs of ventilation service possible. The special processing modules (Wasilewski and Szywacz, 1996) enable, among other things, the

- calculation of mean values in wide time horizons,
- calculation of trends of signals changes,
- determination of dependence of methane emission on air quantity or production at longwall area,
- balance of air and gases quantity in mine areas,
- determination of main fans parameters,
- creation of cross-correlation tables of the disturbances propagation in network, so called, smokiness time etc.

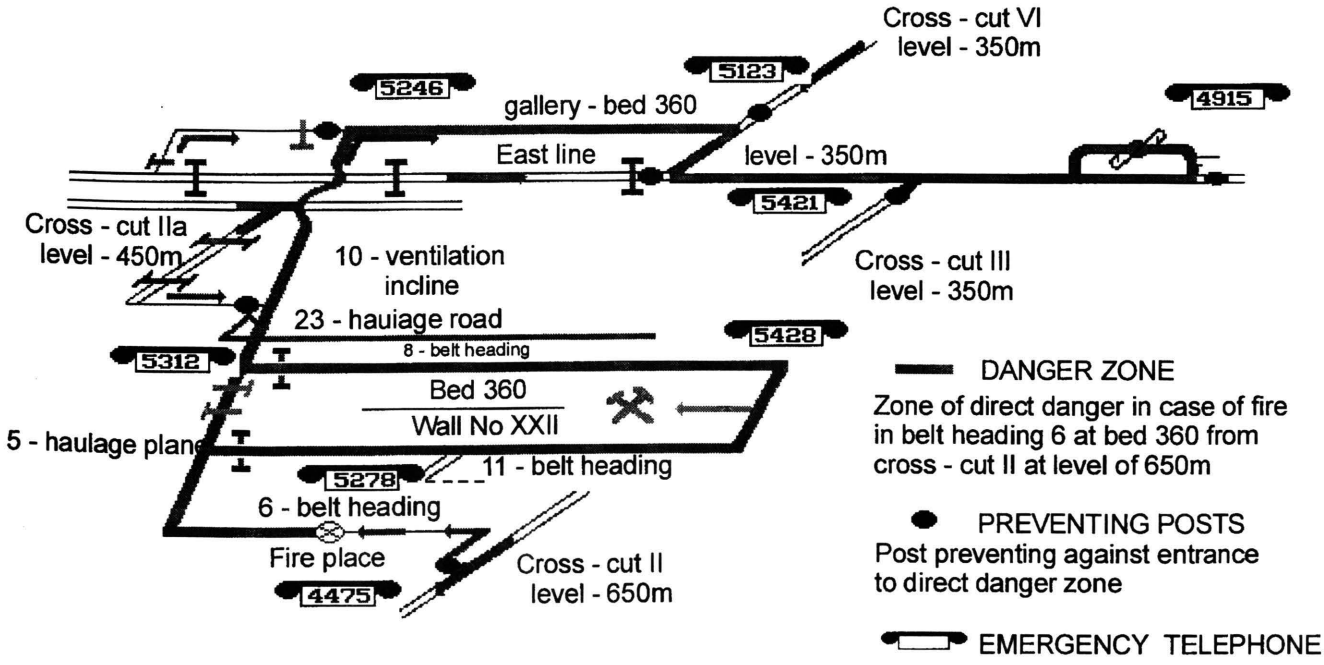


*Figure 4. Danger zone, fire preventing posts and emergency telephone in controlled areas.*

### RealTime Mine Smokiness

Coal production activities in mining areas, mainly shooting or welding, results in frequent disturbances in concentration of gases which move in the direction of airflow. These disturbances recorded by the system can be used as "natural tracer gases" to determine realtime and velocities of disturbances movement along underground workings. In the computer-based monitoring system, these parameters can be determined automatically, without an operator, e.g., by the cross-correlation method (Wasilewski, 1997). Time and velocity of disturbance propagation can be used by mine staff for checking stopping tightness and air escapes, as well as the determination of realtime propagation of smoke and fire gases. Knowledge of real smokiness times will greatly enhance efficiency of a staff rescue operation. The idea of using a cross-correlation function for determination of smokiness times is shown in Figure 5.

Computer Processing and Recording of Manual Measurements

It is the general feeling that mine ventilation departments should fully utilize the computerized manual measurement results. The analysis of measurement maintained by ventilation department has shown that the present mining regulations and the range of measurements as well as the required inspection cycle of individual inscriptions to the books, make it impossible to record measurements entirely using computers.

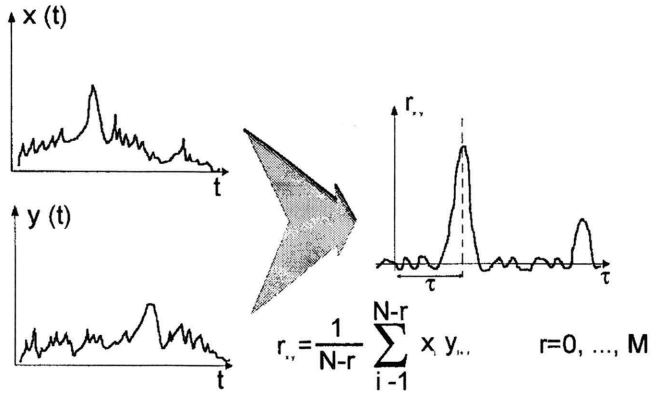


*Figure 5. The idea of using cross-correlation function for determination of smokiness times.*

Use of computer documentation would be possible after simplifying the procedures. One can follow the solution of data protection used in banks where the different levels of inspection and confirmation of operations on data are used. In the expert system, the computer technique can be used, in the first place, for keeping:

- Main Ventilation and Early Fire Detection Books,
- Separate Ventilation Project with layout of sensors and control chart of ventilation condition and gas content in a working,
- Document distribution of gas and dust test results.

**Computer Book of Early Fire Detection.** This makes use of analytical and graphical features of a computer and enables automation and standard solutions. The computer book provides evidence of measurements and determination of the indexes for fire hazard estimation.

The computer book includes a specialized editor of measuring data which enables to archiving data in a database followed by processing in accordance with the accepted algorithms. Data editing is performed directly in a mine laboratory by entering the air samples analyses of for particular measuring stations.

The competent mine service and supervising staff are responsible for everyday inspection of the analyses. This fact is verified by a time stamp introduced by a coded (password) command. The developed graphic interface enables the users to check the data on a scrolling windows and due to "drop in" option the data display within accuracy of a single measurement (date, time and measuring value) is possible. The measuring data from the database can be displayed and printed in a form of reports and statements.

In the expert system, the air measurements and analysis results, immediately after entering into mine laboratory and the indexes of fire hazard, are available in the ventilation department and command headquarters. All data are worked on a measuring station and can be checked on schematic diagrams.

## HARDWARE AND SOFTWARE STRUCTURE OF THE SYSTEM

The expert system requires suitable hardware, software, and for its operation the following facilities have to be put in place in the mine:

- hazard monitoring and ventilation control system, e.g. type SMP,
- computer mine network with operating system WINDOWS NT,
- supervising and management system type ZEFIR,

and additionally in ventilation department and action headquarters:

- terminals of ZEFIR system
- licensed firmware type DELPHI
- programs of network calculation and analysis type VENTGRAPH,
- programs of engineering calculations.

Compliance with these requirements will introduce the expert system for hazard monitoring and ventilation control. All software of expert system is developed in Delphi ver 3.2 and run on a Windows NT operating system. In addition, in command headquarters a projector making a large-screened synoptic table should be available. In the beginning of 1998 the expert system was installed at hard coal mine PNIOWEK where it passed tests successfully and now is in normal operation.

## SUMMARY

Providing autonomous protection functions of methanometry and early fire detection, the integrated hazard monitoring system in mine makes a useful tool for mine ventilation service. The hazard and ventilation monitoring systems are the sources of a great number of measuring data recorded on the surface. Many years of observation have shown that besides hazard monitoring it is possible to make use of these data for identification of ventilation process

parameters using a computer method for data processing. The expert system and new software tools allow complex work of ventilation, fire-fighting and protection using the current and archived data from automatic measuring systems and manual measurements.

The idea of the expert system for supervising staff within hazard monitoring will contribute to the improvement by mine safety by increased reliability in calculations made by Ventilation Engineers. The system will be helpful to improve of staff rescue operation in case of fire and during a fire-fighting and to minimize risk during fire-fighting operation.

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