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IMPORTANCE OF MEASURING INSTRUMENTATION IN THE ASPECT OF THE METHANE EXPLOSION HAZARD AND GEOPHYSICAL HAZARDS

1. Introduction

Permanent progress in science and experience accumulated as a result of disasters caused by specific reasons enable continuous expansion of knowledge on the possible hazards and lead to tuning of adequate regulations that govern mining operations. Mining equipment and machinery is constantly upgraded in terms of occupational safety whilst secure mining technologies are being implemented for underground operations in conjunction with better organization of work, use of advanced control and measurement instrumentation for both one-shot measurements and permanent monitoring.

Metrology is the branch of science that has been played and is permanently playing an important role in the process of hazard control [10, 14, 13]. Dynamic progress in that branch is closely associated with progress of science and technology, in particular in electrical engineering, electronics and computer science [11]. Increasing level of hazards gave also a spur to speed up designing of new measuring and control instruments [5].

2. Importance of hazards monitoring

In Polish in early 60s of the previous century, when construction of coal mines in the Rybnik Coal Basin (ROW) was launched and coal extraction therein started, fire hazards were supplemented with hazards of methane explosions. It is why use of fixed methane gauges monitors was set compulsory and appropriate control systems were designed to cut off electric

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power supply in endangered regions. Automatic measurement of methane concentration was initially used only in coal seams with the highest category of methane hazard and based on domestic solutions (methane “Barbara-ROW”). Later on, in 70s, due to permanently increasing hazard level, central control systems were imported from France with subsequent purchasing of a license to manufacture them in Poland and to extend their application area to regions with lower level of methane hazard.

In turn, the break of 70s and 80s of the previous century witnessed an increasing hazard from rock bumps, which was associated with deeper and deeper levels of coal extraction. Early measurement instruments (of the SSA-1 type) based on tracking signals from geophones installed in underground excavations with use of self-writing recorders with slow transfer of a paper tape. The first automatic system based on seismic and acoustic method (SAK) was developed in early 80s whilst the micro seismology was harnessed some later to develop the system SYLOK. Owing to fast progress in microprocessor technology, these systems could be substituted in early 90s with the systems for rock bump control called ARES and ARAMIS [1].

Starting from the early 90s the problem of combined hazards (coincidence of methane, fire, rock bump and coal dust explosion risks) proved to be more and more significant. It increased the probability that emergency and critical states might happen in mining enterprises. Therefore, adequate handling the information on hazard levels combined with monitoring of technological processes became the problem of crucial importance, essential for safety of the personnel. It gave spur to central control and supervising over safety of mining staff in order to visually present variations of parameters attributable to pre-programmed and monitored processes with use of dynamic synoptic tables. Due to simultaneously increased importance of monitoring and supervising over associated hazards it was not only the engineer-in-chief who was in charge of all the control systems but also the supervisors of methane monitoring system and the rock bumping warning network started to play important roles. It proved to be necessary to integrate all the alerting and messaging subsystems into a unified control and supervising network with a logical hierarchy and a multi-level structure for monitoring the process of coal extraction and mining safety issues (SD2000). It is an open system that enables to connect and integrate new, subsequent subsystems and modules [15].

3. Monitoring of gas hazards

Similar investigations as well as other research projects in the same field were launched in Poland and in other countries, in particular in the former Soviet Union [9]. The achieved results demonstrated wide variety of methane ignition initiators. They can be classified into the following groups [12]:

- evident initiators, where locations of them is accessible, thus environmental conditions in such locations can be monitored;

- hidden initiators that may occur in inaccessible locations, therefore direct monitoring of them is infeasible.

Evident initiators include:

- endogenous fires that give off heat with sufficiently high temperature and prolonged durations,
- blasting operations, due to:
 - extremely high temperature that is reached during ignition of explosives (the ignition temperature of explosives is from 2 to more than 4 times higher than the minimum flash point of methane);
 - possible deflagration of explosives inside blastholes;
- mechanical sparking of rocks that are produced while mining with shearers or during haulage of the output (hits of rocks against other materials),
- mechanical sparking of mining equipment friction, e.g. the cutting head (bits) against canopies of powered roof support units, friction of the conveyor chain,
- electric arcs — e.g. from electric equipment, supplying cables, sparking of electric traction,
- electrostatic discharges, due to application of plastic materials that is sometimes used in underground excavations,
- open fire in operable excavations, e.g. from technological processes that involve cutting or welding of metals, smoking.

The group of hidden initializers comprises the following:

- mechanical sparking of rock in goafs caused by internal friction between rock lumps,
- high energy and flow of electrostatic electricity that may occur in goafs — in fissures formed as a result of rock cracking,
- sparks of electrostatic charges that may arise in goafs during destruction of hard rock integrity,
- hot surfaces that origin in goafs due to high energy that tears off rock structures or after the phenomena of internal friction between rock lumps.

The development of the system methods of gas hazards monitoring in hard coal mines has been initiated just in the 70-s of the last century. The first systems implemented in Polish mines aimed at minimising of methane explosion hazard and were limited to cyclic concentration controls of this gas in selected mine workings. At the end of 70-s the first computer-based system CMC-1 was developed, tested and successfully implemented into production by EMAG. Apart of methane the system monitored some other ventilation parameters like airflow velocity and temperature with 4-minute sampling time.

The range of control has been gradually extended by measurements of other air parameters. The systems which are used nowadays in the hard coal mining provide for a comprehensive

continuous control of the mining atmosphere and they are usually called mine ventilation monitoring systems or mine environment monitoring systems. The systems consist in their underground part of intrinsically safe instruments designed for continuous measurement of gas concentrations (methane, carbon monoxide and carbon dioxide, oxygen) and physical parameters of the air (temperature, pressure, humidity, airflow velocity). Furthermore there are also used binary sensors for state control of ventilation facilities (dams, main and auxiliary fans). The measuring signals are transmitted by cable networks with determined sampling periods to a surface mine control room for on-line presentation, processing and archiving. The monitoring systems ensure warning and alarm signalling and in case of methane hazard they additionally provide for automatic safety shut-down in areas where the methane concentration levels exceed the allowable values defined in mining regulations.

The SMP-NT/A system, developed in 2006 [8], is a complex solution to the issue of monitoring all the safety parameters in mines, in accordance with the relevant Polish regulations.

The system comprises the following (Fig. 1): surface station equipment, underground field devices (methane monitors MM-4, outstations MCCD-01), variety of analogue sensors of mine air parameters (CO, CO₂, temperature, airflow velocity etc.), binary sensors for ventilation equipment control and a suitable surface IT infrastructure.

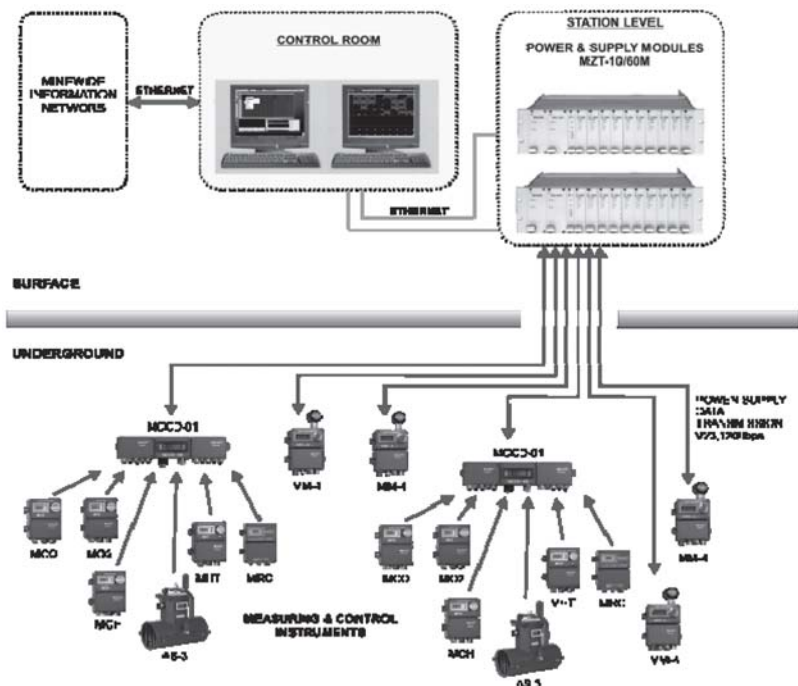


Fig. 1. Structure of the SMP-NT/A system

Apart of measurements the field devices have the function of automatic (practically immediate) switching-off power supply in case of gas explosion danger. In the underground part of the system only intrinsically safe instruments are used, adapted to remote power supply from the surface station. This quality is of key significance in the case of mines with high level of gas hazards as it enables to continuously monitor the environment in any conditions, irrespective of the state of the underground electric power network. Both the measurement part and the IT infrastructure have a module-based structure, which can be easily tailored to the size of the monitored plant and functions required by the user.

4. Rock-bump hazard monitoring

Research and implementation work on bump hazard monitoring were initiated in EMAG in 60-s of the last century, first system solution were introduced into practice in 70-s [2]. Further development went practically simultaneously with research on gas hazard monitoring systems using the new appliances of measuring, electronic and IT technology. Now the modern, intrinsically safe seismo-acoustic and microseismic systems are commonly used in Polish coal and copper mines as well as abroad.

The newest, described further on, solutions of bump hazard monitoring ARES-5/E and ARAMIS M/E have been developed in cooperation with the Institute for Complex Managing of Natural Resources at the Russian Science Academy of Moscow, the ISSI International Ltd of Stellenbosh in South Africa and Tuzla University of Bosnia and Herzegovina [4, 3]. The project was designed to develop and apply the new system SAFECOMINE in order to monitor and predict seismic and environmental hazards in underground and open pit mines.

The ARES-5/E system (Fig. 2) has been developed to assess rock-bump hazards in mines, in accordance with the principles included in the seismo-acoustic method for hazards assessment which is in force in Polish mines. A basic task of the system is to process, by means of SP 5.28/E geophone probes, the velocity of mechanical strata vibrations, and then, after amplification and filtration in N/TSA-5.28/E transmitters, the transfer of the measured signals to the Geophysical Centre on the surface by means of a telecommunications cable network and receiving circuits of the OA 5/E surface station. Digital processing of obtained signals and their computer interpretation is performed at the surface part of the system.

The software being applied perceives the ARES-5/E cassette modules as one 64-channel module, so the data recorded by particular geophones can be configured, grouped and presented on the monitor screen according to a user's request. On the screen, both minute, hour and shift data recorded in different channels can be observed at the same time. The example of a printout of a seismo-acoustic activity diagram, performed for the selected time interval including marked bumps of minimum energy, is shown in Figure 3.

The ARAMIS M/E seismic system, together with the digital DTSS transmission module, permits tremor location, determining the energy of tremors occurring in the mine as well as seismic hazard estimation.

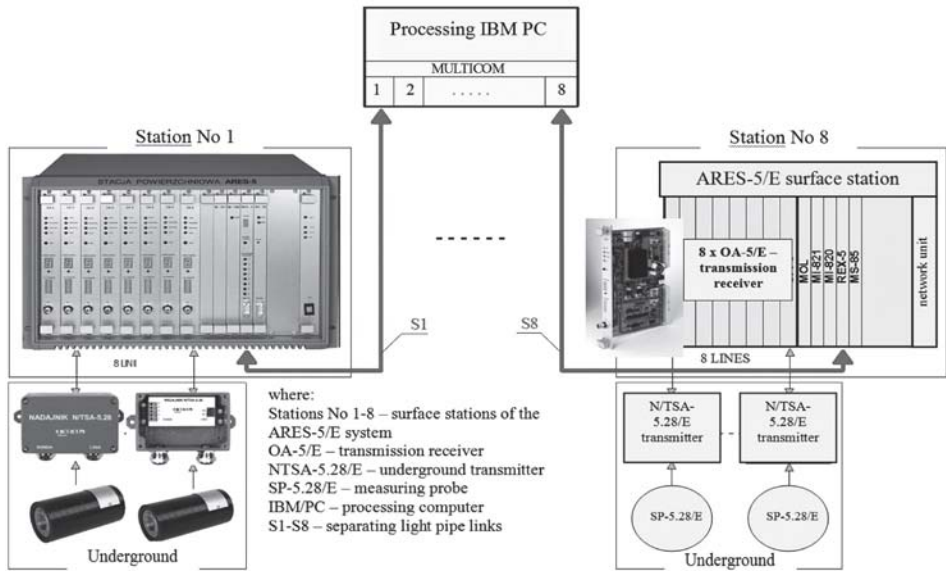


Fig. 2. Structure of the ARES-5/E system

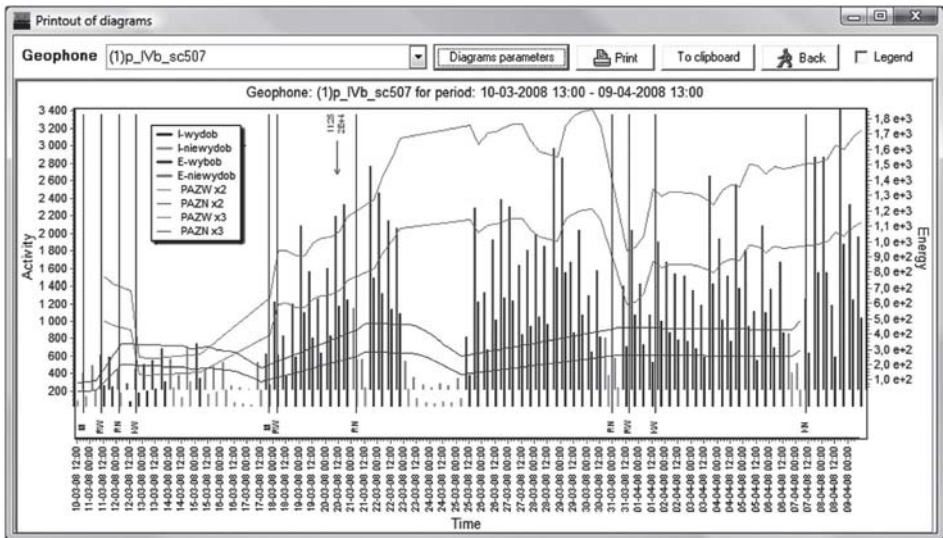


Fig. 3. Printout of a seismo-acoustic activity diagram for the selected time interval

The DTSS intrinsically safe seismic transmission module provides the mains supply of underground transmitters from the surface, signal digitalisation at the seismic sensor site and

transmission to the surface. A high level of registration dynamics of 110 dB, 0–150 Hz frequency band and interference-resistant transmission provide correct, saturation-free registration of low energy (10^2 J), as well as high energy signals, and identification of their characteristic phases. According to the extent of the mining area, the system is based on seismometers or, optionally, on low frequency geophones. The equipment is intrinsically safe and centrally powered from the surface. Digital data transmission allows triaxial transmitting (X, Y, Z) of the ground velocity movements by a single telemetric line. Signal sampling is performed by 24-bit Sigma Delta converters, providing high dynamics of conversion and recording. The system also allows continuous, on-line registration of seismic signals with the help of a recording server. The standard software provides registration of a single signal component per channel. An optional 3-component DTSS system requires a non-standard software version allowing using tri-axial seismic sensors (seismometers or geophones).

A schematic diagram of the ARAMIS M/E system with DTSS digital transmission module is shown in Figure 4.

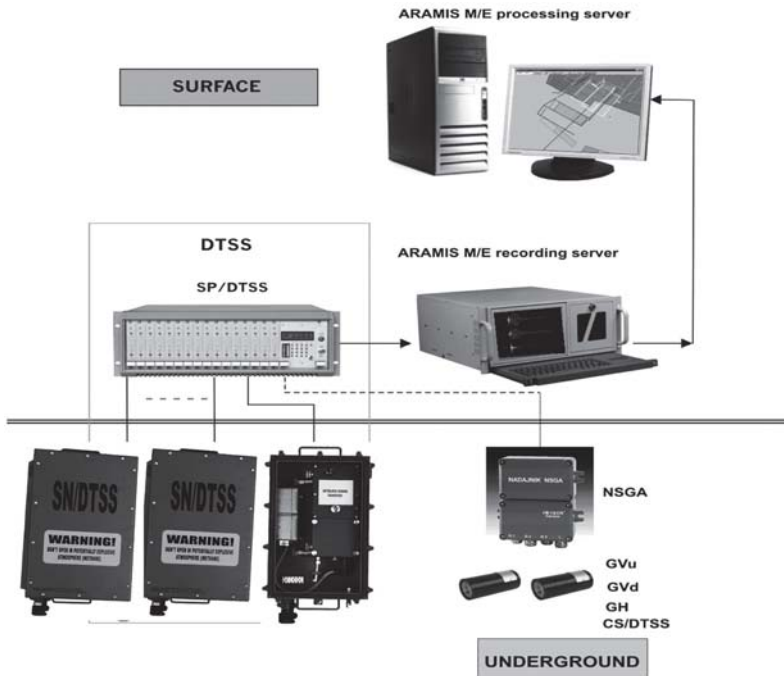


Fig. 4. Schematic diagram of ARAMIS M/E system

In a standard version, the ARAMIS M/E seismic system is fitted with the ARAMIS_WIN software which enables continuous monitoring and archiving of seismic events in underground mines.

Apart of the described above autonomously performed function the ARES and ARAMIS systems can interact i.e. send data for further processing in another very useful in mine practice programs such as:

- ARES_OCENA software used with the ARES-5/E system (linking recorded data for better location of seismic events),
- ARAMIS_WIN/E software used with the ARAMIS M/E system (linking recorded data in adjacent mines for better location of seismic events),
- HESTIA software (transmitting the event data to the global database and supplying other data, e.g. names of workings or areas, etc.).

The data can also be sent on-line to the special software designed for so called integrated systems of environmental hazards which are used in mines where high level of methane and bump hazards occur simultaneously and influence each other.

5. Summary

To be competitive a coal mine is forced to use modern highly efficient coal extracting technology which is the main reason for increase of environmental hazards. In addition, the process of exhausting shallow coal beds causes deeper and deeper coal exploitation and, due to this factor, the number of environmental hazards is also increasing. The most dangerous in Polish coal mines are gas and rock-bumps hazards.

Reconnaissance of actual hazard levels due to methane inflow to no extent can be merely limited to monitoring of its parameters and protection of endangered regions by automatic methane metering systems, as such systems can be considered only as an auxiliary tool.

The presented functionalities and capabilities of systematic and comprehensive systems dedicated to monitoring of associated and combined hazards serve as a background to state that it is possible to be vigilant and undertake appropriate protective measures against consequences of hidden initializers as well as evident ones, such as endogenous fires, sparking caused by hits of rocks against other materials, sparking caused by mechanical friction of various parts in the equipment, electric arcs or open fire in extracted excavations.

To assure the proper level of safety in such conditions continuous research on new method of environmental monitoring has to be carried out and the results implemented into mine practice.

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