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The porential for monitoring air parameters in the determination of carbon monoxide sources in light of research projects

First, a recapitulation is provided of monitoring systems, based on electronic solutions which ensure the reliability of the requisite speed and measurements while intrinsically safe. Subsequently, examples of measurements of the carbon monoxide concentrations emitted by different sources are presented. In the context of the different characteristics of changes in carbon monoxide concentration, the problem of the identification of carbon monoxide source generated during high energy rock burst is discussed. To alt a better understanding of the issue, the conditions of mine development work in areas threatened by bumping hazards as well as mining procedures in seams in this type of hard coal deposit, is presented. Finally, the results of comparative tests of changes in carbon monoxide concentrations and conclusions are given.

Key words: *hazards, monitoring systems, electronics, carbon monoxide sources*

1. INTRODUCTION

In the Polish mining industry, the average depth of mined hard coal seams is greater year by year by about 8 meters. As a result, the mining and geological conditions during development and mining work are becoming increasingly difficult. This process usually leads to an increase in the intensity of hazards which accompany mining work, such as fires, dust, water, coal dust explosions the presence of methane, bumping, gases rock bursts and other climatic hazards. The better the recognition of those hazards at the design stage, the greater in the potential to prepare prophylactic measures ensuring the safety of mining work. However, the interim control of the parameters characterizing the given hazard is most important as it facilitates an immediate reaction to an approaching hazard.

At present, different types of monitoring systems are used from dispatcher systems decision-making process to alarm communication systems for quicker and automatic announcement about possible dangers or the need to evacuate crews from the danger zone. However, it should be noted that not all the hazards can be continuously monitored at present and that there is still much to do in this domain.

Only a fraction of the possibilities of monitoring systems in the control and assessment of areological phenomena is presented in the article. Regarding an incident which took place on 5th May 2018, the potential to control carbon monoxide concentrations in the mine air in question together with automatic assessment of the CO source, is presented.

2. CHARACTERISTICS OF THE MONITORING SYSTEM

Mine aerometry systems are commonly used for the control and assessment of parameters of air flowing in underground mine workings [1]. They typically consist of an automatic gasometrical system and in the presence of methane hazards – an automatic methanometric system. In the case of bumping hazards, the mine aerometry systems are integrated with micro-seismic and seismic-acoustic monitoring systems.

Methanometry has always had a protective function, consisting of automatically switching off machines and power supply equipment in areas where the flowing air has over-standard concentrations of methane. The use of such protective measures in classical gasometry dates back to the middle of first decade of twenty first century. This means for example power supply switch off in the case of drop in air flowrate in the longwall panel or face area with methane explosion hazard or in the case of simultaneous door opening in the ventilation damps stabilizing air flow direction and air output as well as in the case of rock burst of energy exceeding that one specified by a mine crew. In the case of the last situation, cutting off the power supply has to eliminate the potential generation of electric sparks with might occur as a result of the power cable breaking, which in turn could lead to a methane explosion.

In underground mines, a telecommunication system [2] adequate for the given type of mining industry is indispensable for the proper processing of information about measured parameters and for its proper use. Telecommunication [3] is the transmission or receiving of information of any nature by wire, radio, optical and electromagnetic systems. Each monitoring system should guarantee the reliability of data measurement transmission and should have the required speed of data processing. The potential to determine the device's uncertainty in terms of device/sensor (uncertainty in the rated conditions), transmission resolution, resolution of recording the measurements result in a repository as well as the recording format [4, 5], is important. Besides, in underground mines where a methane and/or coal dust explosion hazard is possible, the communication system should meet the following tougher requirements [6]:

- underground telecommunication systems should be intrinsically or optically safe (feature "description" acc. to PN-EN 60079-28 [7]) and should be able to operate in atmosphere of any methane concentration,
- telecommunication devices as well as cooperating devices used in underground mine workings should have a protection level of enclosures with a minimum of IP54 – due to the humidity as the presence salt and dust,
- the use of a branched out structure of the telecommunication network due the small transverse dimension of roadways (up to few meters) in relation to their longitudinal dimension (up to few kilometres); expanse of the workings.

It is also important to ensure maximum effectiveness of the distribution of electrical and telecommunication earthing (including SUPOgiven the risk posed by the cumulation (in a confined space) of high power electrical grids and devices.

The continuity of the power supply of these devices is an important issue with telecommunication systems. While typical restrictions resulting from:

- planned electrical grid shut down (due to e.g. required repairs),
- periodical tests of switching off the electrical devices required by the gasometry systems,
- the unplanned switching off of the electrical devices caused by the activation of electrical and methane metric protection systems,

do not cause significant problems in assessing hazards level, a break in power supply and/or data transmission – e.g. caused by a methane and/or coal dust explosion or a rock burst – can result in stopping the transmission of information from the area affected by such event. In order to assess what may have happened in this area, we need to use indirect methods based on information acquired from area outside of this zone.

3. ASSESSMENT OF CARBON MONOXIDE SOURCE BASED ON THE CHARACTERISTICS OF THE CHANGES IN CO CONCENTRATION

Endogenic fire hazards is a typical hazard in hard coal mines. A carbon monoxide concentration in mine air of above 26 ppm or CO volumes of over 25 dm^3/min is recognized – if the CO is not generated by means of a technological process – as a fire. In such cases, a fire rescue action should be initiated. The standard methods for monitoring the areological hazards can sometimes result in faulty interpretation of the carbon monoxide source and therefore afire rescue action may be unitiated unnecessarily thus generating unjustified costs.

There are many reasons for the appearance of carbon monoxide levels over and above the standard concentration or/and volume, therefore the rapid identification of the CO sources is important [8]. That is why tests for the quick, automatic identification of CO sources were conducted [9] within the framework of the European project: Minimising the risk of and reducing the impact of fire and explosion hazard in underground coal mining industry, co-financed by the Research Fund for Coal and Steel. The development of effective detection procedures for dangerous atmospheres and flammable gases, whilst eliminating the faulty interpretation of increased carbon monoxide concentrations was the main objective of the project (the project was implemented by an international consortium, including the Institute of Innovative Technologies EMAG and the Institute of Mining Technology KOMAG).

The tests conducted enabled the development of model for identifying changes in CO concentrations depending on of its source type (Fig. 1) as well as development of CO source identification subsystem cooperating with the standard monitoring systems.

However, it transpires that the identification of the CO source is far from obvious, as illustrated in the example below.

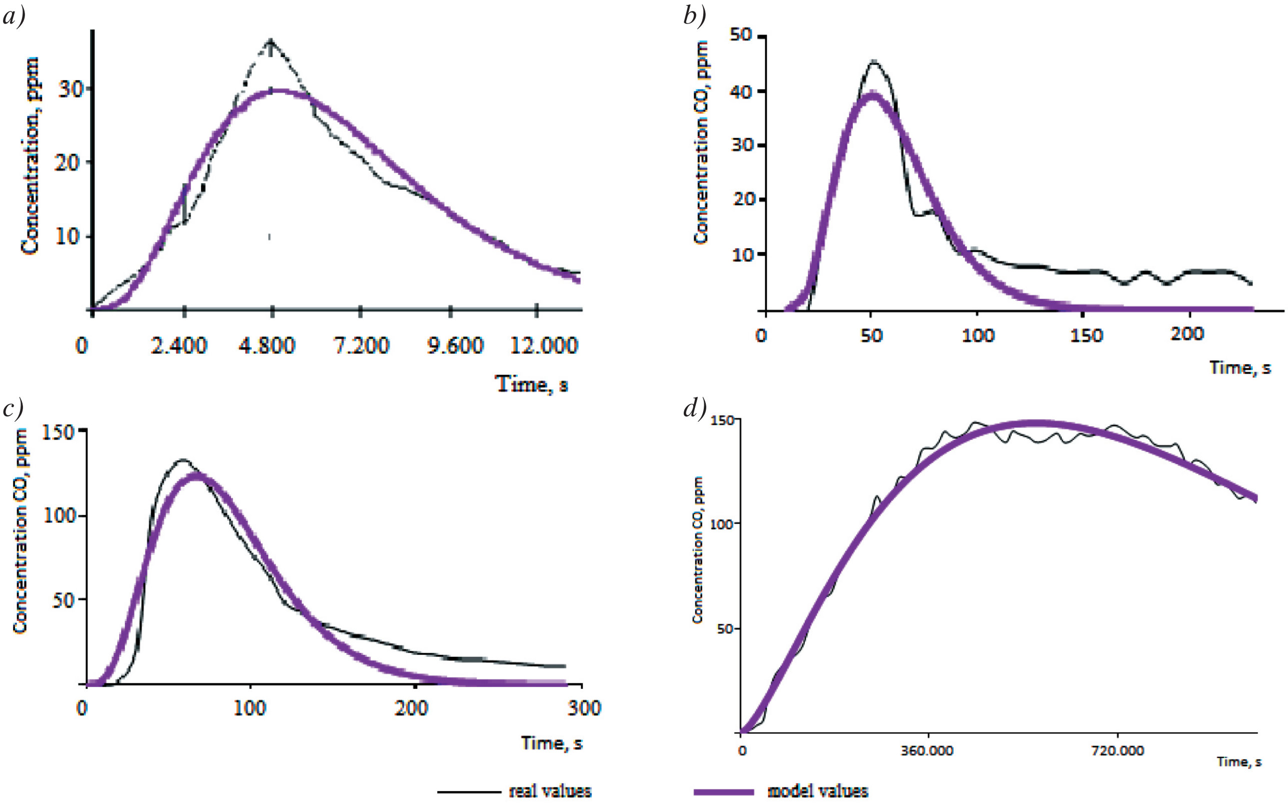

Fig. 1. Models of changes in CO concentration depending on its source: a) results of gas outflow from the gob; b) results of the operation of a diesel machine; c) results of blasting operations d) spontaneous fire [9]

4. DETERMINATION OF CARBON MONOXIDE EMISSION SOURCES IN THE CASE OF ROCK BURSTS AND BLASTING OPERATIONS – AFEASIBILITY STUDY

On 5 May 2018 at 10:58 a.m., a high-energy rock burst ($E = 2.0 \cdot 10^9$ J) occurred. At the beginning the recorded energy was $E = 1.9 \cdot 10^8$ J – Figure 2. About 820 meters of mine roadway sections were affected, in the H part of the 409/4 seam, from a total length of prepared roadways which amount to 2700 m. The President of the State Mining Authority appointed a special commission to investigate the reasons as well as circumstances of this bump [10].

As a result of the bump, the automatic methane sensors installed in this area, as well as the automatic CO sensors stopped operating due to break in power supply and transmission of data measurements. Only the sensors which were outside the affected area remained in were operation (Fig. 3).

The operating methane sensors – MM187 and MM123 – recorded a significant increase in methane concentratios (Fig. 4) (exceedance of permissible concentrations marked in red, permissible concentrations marked in green), similarly the CO sensors M712 and M730, recorded increased concentration but witch much lower dynamics (Fig. 5).

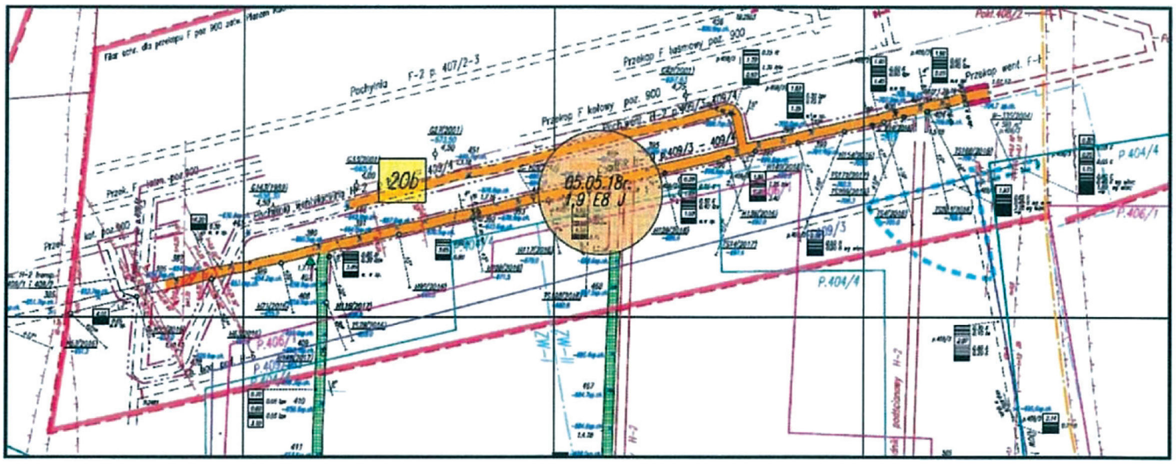

Fig. 2. A fragment of the map of mining headings of 409/4 deck in lot H together with location of the rock burst in the area of mining work [11]

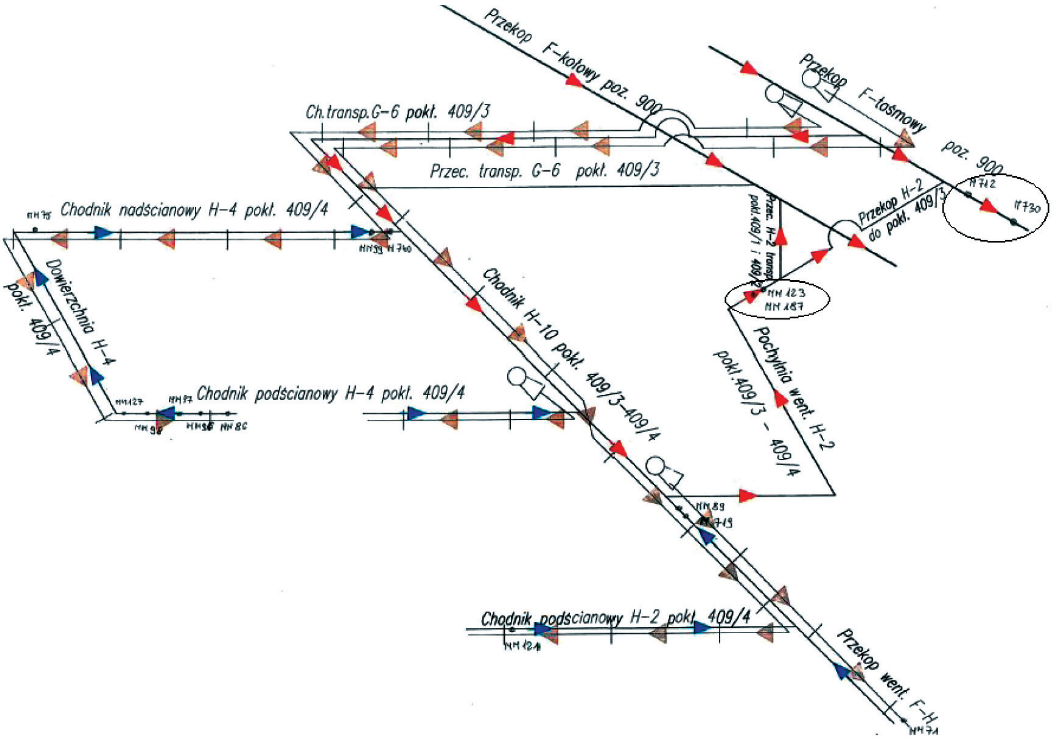

Fig. 3. The ventilation diagram of the H-part of the seam 409/4 with the methane sensors (MM ...) and carbon monoxide sensors (M ...) [11]

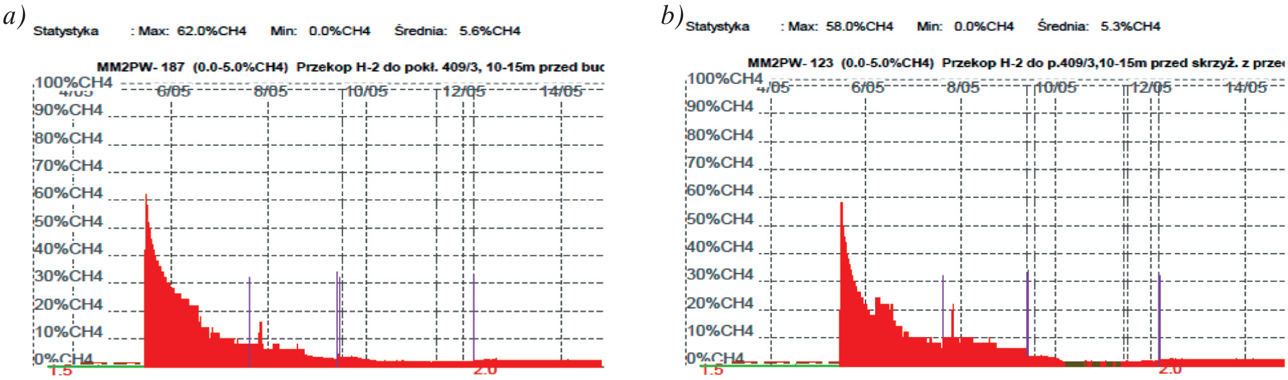

Fig. 4. Indications of the methane detectors before and after the rock burst on 5.05.2018: a) MM187; b) MM123 [11]

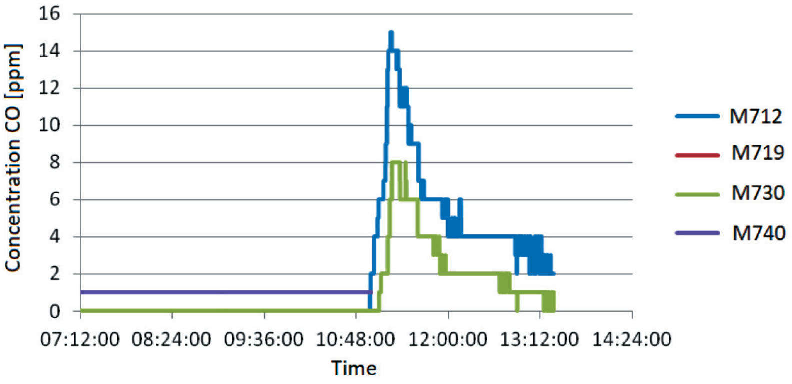

Fig. 5. Indication of carbon monoxide sensors M712 and M730 on 5.05.2018 before and after rock burst [11]

During the work of the commission there were some doubts concerning the reasons for the cause the rock burst, since a blasting operation had been planned at the same time during the development of one of the roadways with the use 7.5 kg of explosives. The blasting holes had already been filled with explosives and fused with an igniter. It was not possible to confirm if the explosives were not accidentally launched, which would have initiated the rock burst. The special investigation was ordered to explain all the doubts [11].

The analysis of the blasting operations (before the rock burst) conducted in the workings of part H of seam 409/4 showed that the changes in CO concentrations recorded by the M712 and M730 sensors are characteristic of a rock burst phenomenon, as presented in Figure 6.

Comparing the above changes with the changes after the rock burst (Fig. 5) it can be found that, after the rock burst, the changes in CO concentration also confirm that the explosives were ignited. However, other facts such as: seismograph records and a statement of the blasting engineer inspecting the face front after the rock burst, did not confirm this. Therefore, it was decided to analyse all CO changes before the rock burst in order, to find other reasons for such an increase in CO concentrations. It transpired that there was a slight increase in the CO concentration during the rock burst witch was not provoked by the blasting operation. Only that, the increases in CO concentration were much lower (Fig. 7). The fact that the energy of these rock bursts was significantly lower than the energy of a rock burst causing a bump was taken to be the starting point for further analyses.

Finding a carbon monoxide source other than blasting with the use of explosives was the next step in the investigation. For that purpose, mining and geological conditions in part H in all coal seams, taking into account the mining history, were analysed. It emerged that over seam 409/4 there was a mined out (in the main part) seam number 409/3. It was determined that, in gob of the seam, different gases including CH_4 and CO might still be present. Extremely high rock burst energy – $E = 2.0 \cdot 10^9$ J – caused unsealing of the rock mass in part H and the migration of gases from the gob of seam 409/3 to the workings of seam 409/4 which despite damages caused by a bump were in under pressure generated by the ventilation main fan.

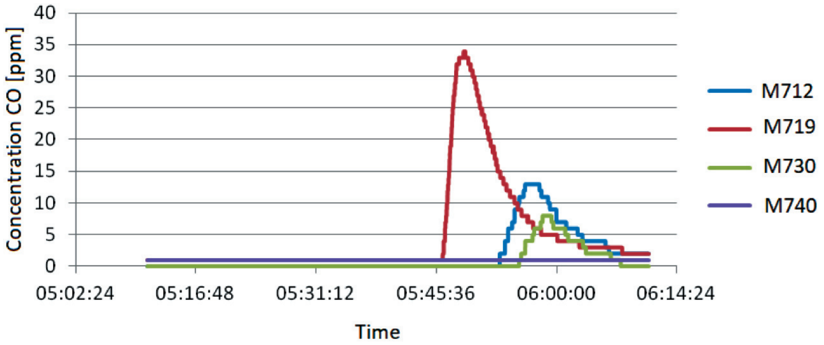

Fig. 6. Example of change in CO concentration on M712 and M730 sensors, relative to M719 and M740 sensors, after blasting operations with use of 7.5 kg explosives [11]

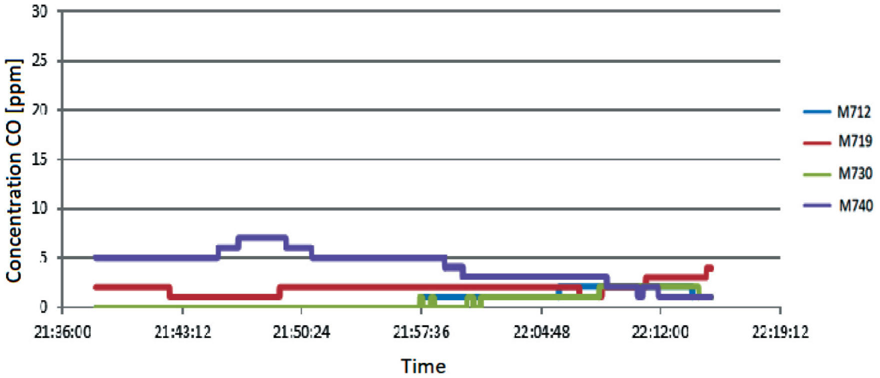

Fig. 7. Changes in CO concentration of individual sensors recorded by each sensor on 25.04.2018 in the H-part after the rock burst at 21:46:26 not related to blasting [11]

This confirmed methane, ethane flow through the area after the bump of volume equal to about 545 000 m^3 [12], part of which was generated in the seam 409/4 and part from the gob of overlying seam. Also carbon monoxide of maximum concentration 15 ppm and total volume 96 m^3, recorded by M712 sensor, entered from the gob. Comparing the characteristics of changes in CO concentration after the bump (Fig. 6) and the changes shown in models of changes in CO concentration (Fig. 1) we can see similarity – considering time of changes – with the model describing the changes associated with flowing of carbon monoxide from the gob (Fig. 1a). Thus, a hypothesis that high-energy rock burst was initiated by blasting operation has not been confirmed.

5. CONCLUSIONS

The various monitoring systems used in Polish mines, dispatcher systems supporting the taking decisions as well as emergency communication systems are used to assess correctly the level of a given hazard, what allows adjusting the preventive measures to the level of concentration changes and – in the case of significant increase of the hazard level, to automatically notify the crew about danger and the need to leave the threatened area.

Monitoring and alarming systems guarantee reliability of measurement and data transmission, as well as high speed of data processing. Incorrect interpretation of the carbon monoxide source may lead to unnecessary initiation of a rescue actions, generating unreasonable costs. The developed CO source identification subsystem, co-operating with standard monitoring systems, allows quick assessment of the CO source, eliminating unjustified fire-fighting rescue actions. In a result of a catastrophic event such as methane explosion, coal dust explosion, bumps – power supply of the monitoring systems can be broken, so data transmission is interrupted and there is no information available from the region.

In the absence of data from a given region, the assessment of the causes of the event and the state of the current level of threats in such a region cause that the assessment of the current state in such a region must be carried out based on the sensors located outside the given zone.

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