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Reducing the methane hazard in the longwalls by means of methane removal from the goafs

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Abstract. This paper presents a method and system for suction of methane-air mixture from a longwall caving during exploitation. This method will significantly reduce or completely eliminate the cases of exceeding permissible methane concentrations (2%) at the longwall ends ensuring safe work for miners, reduce or eliminate interruptions in the exploitation due to shutdowns of electricity by recording-disabling methane detectors, as well as increase the yield from the longwall. This system may be used in longitudinal or transverse longwalls exploited to the coal field boundaries, using the U-ventilation method. This paper refers to the strength calculations of the methane removal boom. The method of operation of the methane removal system was given for low concentrations of methane, below 20%, in the air extracted from the caving. This paper also presents the advantages of methane removal from the longwall caving.

1. Method for methane removal from the longwall caving

In methane mines, in the longitudinal or transverse longwalls exploited to the coal field boundaries, using the U-ventilation method, increased methane concentrations occur at their ends, i.e. close to galleries or top drifts and inside galleries and top drifts themselves. The methane in these places is mainly released from the caving due to the air circulation in the caving rock fissures, consisting of the inflow of air into the caving in the first half of the longwall and the outflow of the methane-air mixture in the second half of the longwall. As shown by studies and calculations from the ventilation model simulations of the caving longwall [1,2], inflows and outflows of gaseous media to and from the caving are not symmetrical along the length of the longwall. The highest amount of air enters the caving at the beginning of the longwall and flows out with methane at its final section [4]. That is why there is a methane hazard at the end of the longwall and in the top heading. Quantitative distribution of air movement in the caving and thus changes in the methane concentration at the outlet from the longwall depend to a large extent on the location of the longwall shearer. This device acts as a local resistance point on the path of air flowing through the longwall, causing changes in the inflow of air to the caving in front of the shearer and the outflow of air from the caving behind the shearer. So if the shearer approaches the end of the longwall, the air with the methane flowing from the caving behind the shearer increases, causing the methane concentration to rise in the longwall and often exceed its permissible level (2%), resulting in the reaction of recording-disabling methane detectors located at the final section of the longwall. This increased outflow of the methane-air mixture from the final section of the longwall caving can be stopped or significantly reduced by using a method of continuous extraction of the methane infused air out of the caving. This effect can be achieved by installing the methane removal system in the longwall [5,6,7,8,9,10].

2. Installation of methane removal system

Methane removal from the caving in the final section of the longwall can be used in case of longitudinal or transverse longwalls exploited to the coal field boundaries, using the U-ventilation method. These deposit exploitation system and ventilation system are mostly used due to low



operating costs. However, it still causes serious methane problems. The system for methane removal from the caving consists of a set of booms, i.e. pipes, placed in the caving on the floor, attached to the cradles of the longwall conveyor and pulled during the movement of conveyor and powered roof support. The booms are connected with flexible ducts to the main methane removal pipe in the top heading or a local suction system. The method for methane removal from longwall caving with the aforementioned system and using the U-ventilation method, are shown in figures 1 and 2 along with the drawing of the system. The principle of methane removal from the caving in the final section of the longwall is shown schematically in figure 3. A boom in the caving located on the floor in which the negative pressure is created extracts the methane-air mixture from the caving. This negative pressure present at the end of the boom causes a change in the distribution of aerodynamic potentials in the caving. The air in the caving instead of flowing into the longwall space will change its direction, i.e. it will flow into the boom. At a further distance from the boom the air in the caving will be stopped or its outflow to the longwall will be reduced, which will result in a decrease in methane concentration in the longwall.

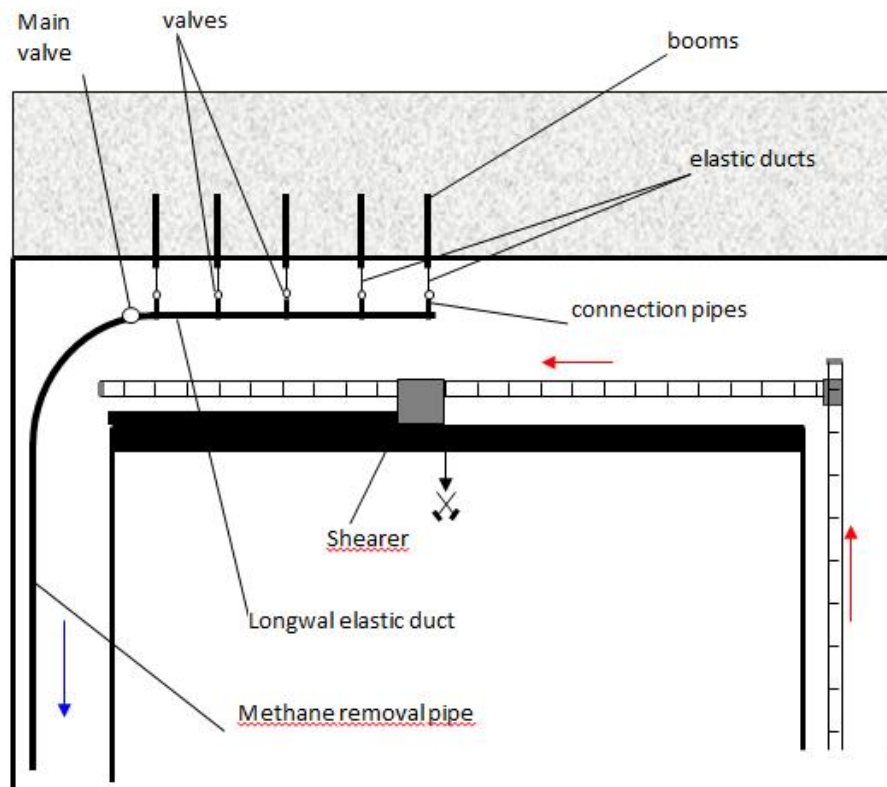


Figure 1. Model of direct methane removal from the longwall caving zone.

The initial strength calculations for the boom involved:

- determining the load of the boom;
- determining the strength necessary to move it;
- strength calculations for the boom pipe.

The calculations were made using the finite element method and various computer simulations [1, 2]. Analysis of the calculation results and comparison of the level of boom pipe effort with the strength parameters of steel from which pipes can be made (for the assumed load conditions) allows to conclude that the boom fulfils the strength requirements.

Research into resistance of 10 meters length boom were carried out in a longwall of Staszic coal mine. The boom fulfilled resistance parameters.

Elements of the system for methane removal from the caving include numerous patents owned by the Silesian University of Technology.

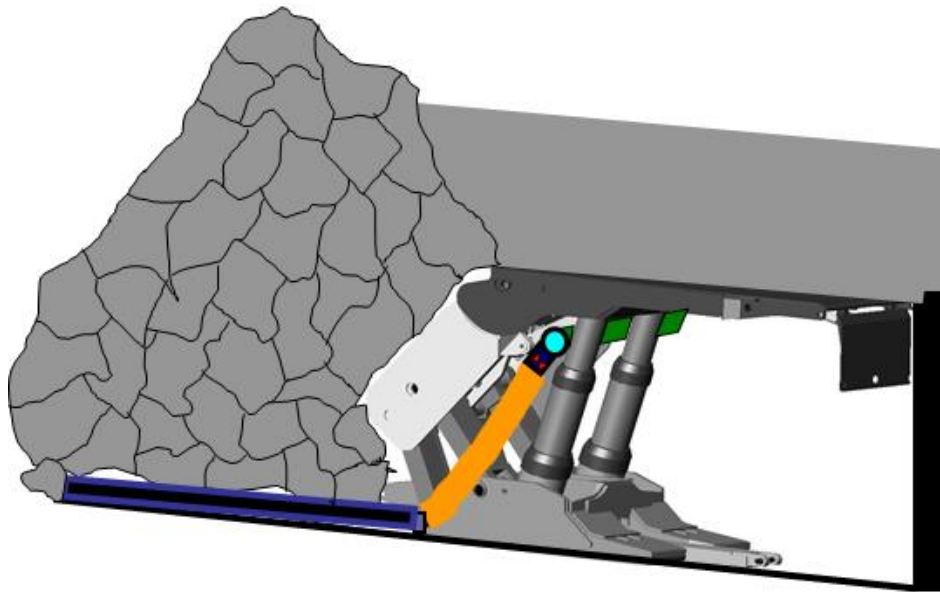


Figure 2. Drawing of the system for methane removal from the longwall caving.

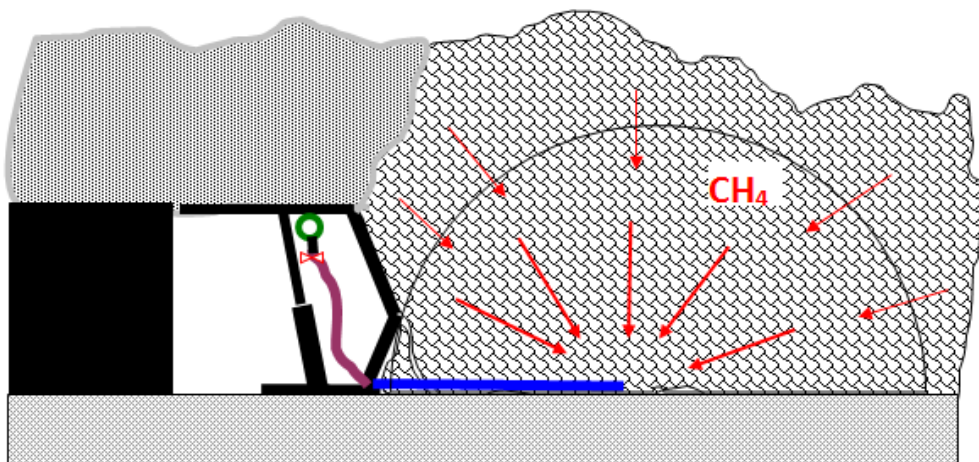


Figure 3. Sketch illustrating the flow of the methane-air mixture in the caving to the methane removal boom.

3. Methane concentration in the system ducts

The methane concentration in the system for methane removal from the caving can take different values. Assuming the boom length equal to 10 or 15 m (the length depends on field tests in various longwalls) we can achieve methane concentration exceeding 20%, which guarantees the safety of the system from explosion. In the case of lower methane concentration, especially within the explosion limits, i.e. from 5 to 15%, an inert gas should be introduced to the system, i.e. nitrogen or carbon dioxide. From Coward's chart or its modification, taking into account the nitrogen axis (figure 4) [3], it is possible to determine changes in gas concentrations, i.e. methane and nitrogen, in the case of feeding nitrogen or carbon dioxide to the system in order to leave the explosive triangle or reduce oxygen concentration to its methane-safe value, i.e. below 12%.

Let us analyse the example shown in figure 4, where the methane concentration in the air mixture extracted from the caving is equal to 10% (point D). The line drawn from point D to point B, the apex of the triangle where we have 100% nitrogen, determines how the concentrations of gases in the air

(oxygen, methane, and nitrogen) change during the introduction of nitrogen. Figure 4 shows that by adding nitrogen to the methane-air mixture with methane concentration of 10%, in order for the oxygen concentration to reach 12%, the concentration of nitrogen will increase to 81% and methane will decrease to 6% (point E). Thus, with the known volumetric flow rate of the air mixture extracted from the caving, for example for $1 \text{ m}^3/\text{s}$, or $60 \text{ m}^3/\text{min}$, with 10% methane, 19% oxygen, and 71% nitrogen, to obtain 12% oxygen concentration and 81% nitrogen concentration, we must add $0.52 \text{ m}^3/\text{s} = 31.2 \text{ m}^3/\text{min}$ of nitrogen, i.e. nitrogen in the amount equal to about 50% of the air extracted from the caving. For other volumetric expenditures of methane air extracted from the caving, the volume fraction of added nitrogen should be the same, i.e. higher than 50%. To ensure safety in the case of methane concentration in air extracted from the caving being lower than 20%, a 50% fraction of nitrogen should also be retained, although at methane concentrations higher or lower than 10%, i.e. the approximate stoichiometric concentration, leaving the range of the explosive triangle is faster. A 50% fraction of nitrogen introduced to the air extracted from the caving with a methane concentration below 20% in relation to its volume output is the minimal value and, also for safety reasons, should be increased by at least 10%.

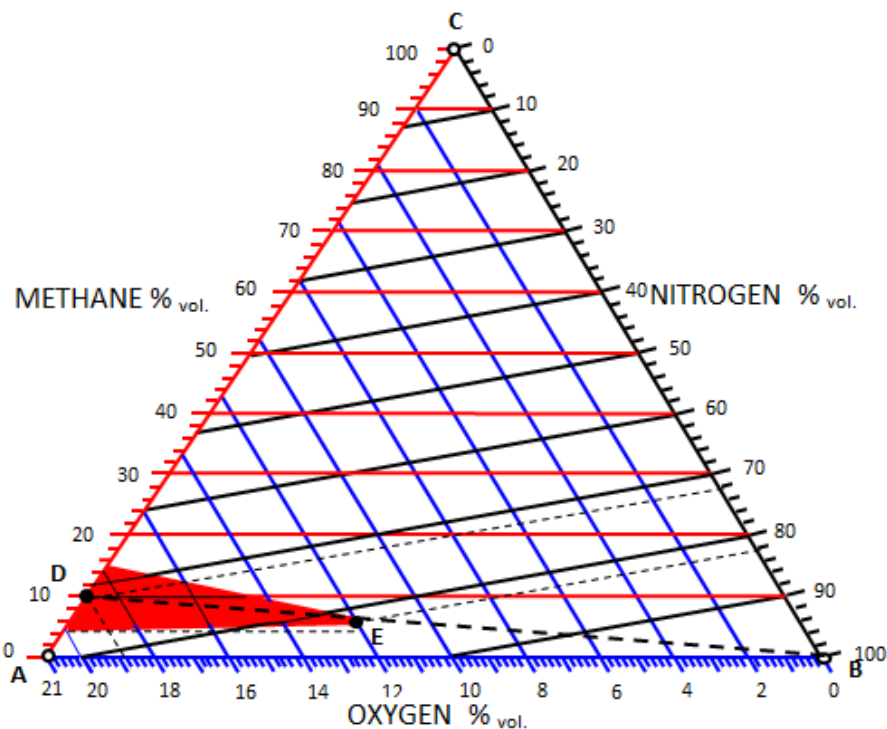


Figure 4. Triangle of gas mixture in atmospheric air with the methane explosion triangle.

4. Conclusions

The advantages of methane removal from caving in the longitudinal or transverse longwalls exploited to the coal field boundaries, using the U-ventilation method include:

- reduction of methane concentration in the longwall area and thus in the ventilation network;
- reduction or elimination of the number of permissible cases exceeding the methane concentrations at the end of the longwall and in top headings;
- possibility of a significant increase in the output of the longwall, which is currently limited due to the methane hazard;
- possibility of effective ventilation of strongly methane deposits using the U-ventilation method;
- application of nitrogen or carbon dioxide to the air extracted from the caving with methane concentration below 20% will reduce the oxygen concentration in this mixture below 12%

which will render it safe from methane explosion. The amount of inert gas to be introduced should be 50% higher than the total methane-air mixture extracted from the caving.

5. References

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