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New Method for the Quantitative Determination of Air Leakages through Goafs

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Abstract: In underground coal mining, the occupational health and safety conditions mainly depend on the management of the ventilation network. A major component for the management of the ventilation networks is represented by the flows which are lost through goafs. The methods for the determination of flow losses through goafs are of quantitative and qualitative type. In order to determine the quantitative air leakages through goafs, INCD INSEMEX Petrosani has carried out a series of measurements and experiments in coal faces from Jiu Valley coal mines. With respect to the quantitative methods, this paperwork presents the method that uses the absolute carbon oxide flow.

Keywords: ventilation, air leakages, goaf, determination methods.

1. Introduction

For the underground exploitation of hard coals, a complex network of mining works for opening, preparation and exploitation is developed. Related to this network of mining works we have the ventilation network over which there are circulated high air flows by using powerful fans located at the surface within the main ventilation stations.

Large depressions generated by these fans generate air leakages through goafs from the level of the coal faces. These air leakages may lead to the occurrence of spontaneous combustion type phenomena.

In order to prevent the occurrence of such phenomena it is important for us to know the lost air flows. One of the methods for determining the lost air flows is the one that uses the absolute carbon oxide flow.

2. Experimental

For the quantitative determination of air leakages through goafs by using the absolute carbon oxide flow q_{co} method there have been carried out a series of experiments at several mining units from Jiu Valley coal field. The experiments consisted in in situ measurements and subsequently in using the absolute carbon oxide flow in order to determine the air leakages through goafs.

The absolute carbon oxide flow q_{CO} is calculated using the following equation:

$$q_{CO} = Q \cdot c \cdot 10^{-3} \quad (L/min)$$

where: Q – circulated air flow over the mining work (m^3/min); C – carbon oxide concentration (ppm); 10^{-3} - levelling factor

The method can be used in every underground mining unit where carbon oxide resulted from the oxidation process occurs.

3. Results and Discussion

3.1. Absolute carbon oxide flow applied to the undermined coal face no. 433/3/II from Petrila Mining Unit.

The analysed coal face presents concentrations of carbon oxide at the level of active mining works, concentrations which are not specific for the current works in normal conditions but which are specific for a special transitory time period over which the activities have been developed under the protection of rescue apparatus. By applying this determination method in an undermined coal bed method for a thick layer of high inclination: coal bed B.S. no. 433/3/II from Petrila Mining Unit, Fig.1, the following results are obtained:

- at the level of the floor directional gallery, branch 7-8, the absolute carbon oxide flow has been: $q_{CO\ 7\text{-}8} = 143 \cdot 450 \cdot 10^{-3}$ = 64,35 L/min CO

- at the level of the transversal sub-layer gallery over the floor, branch 8-9, by applying Kirchhoff's first law in junction 8, we will have:

$$C_{7\text{-}8} \cdot Q_{7\text{-}8} \cdot 10^{-3} + c_{5\text{-}8} \cdot Q_{5\text{-}8} \cdot 10^{-3} = c_{8\text{-}9} \cdot Q_{8\text{-}9} \cdot 10^{-3},$$

in the case in which $c_{5\text{-}8} = 0$, then: $c_{8\text{-}9} = c_{7\text{-}8} \cdot Q_{7\text{-}8} / Q_{8\text{-}9}$ so the concentration of carbon oxide has been: $c_{8\text{-}9} = 450 \cdot 143/205$ = 314 ppm CO

- at he the level of the rising from the floor, branch 9-11, by applying Kirchhoff's first law in junction 9, we have:

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$$C_{8-9} \cdot Q_{8-9} \cdot 10^{-3} + c_{2-9} \cdot Q_{2-9} \cdot 10^{-3} = c_{9-11} \cdot Q_{9-11} \cdot 10^{-3}$$

in the case in which $c_{2-9} = 0$, then $c_{9-11} = c_{8-9} \cdot Q_{8-9} / Q_{9-11}$, so the concentration of carbon oxide has been: $c_{9-11} = 314 \cdot 205/305 = 211$ ppm CO

- at the level of the transversal head gallery, branch 10-11, the absolute carbon oxide flow has been: $q_{CO\ 10-11} = 300 \cdot 200 \cdot 10^{3} = 60$ L/min CO

- at the level of the transversal head gallery, branch 9-10, by applying the Continuity law, respectively Kirchhoff's first law in junction 10, we have:

$$q_{CO\ 8-10} + q_{CO\ 9-10} = q_{CO\ 10-11}$$

resulting that the absolute carbon oxide flow has been: $q_{CO\ 9-10} = 60 - 64{,}35 = -4{,}35$ L/min CO

Which means that an absolute carbon oxide flow over the direction of the active mining work-goaf is lost, branch 10-9. So, in the case in which $c_{9-10} = c_{8-10}$, there can be deduced the air flow which is lost through the dam from the head gallery, towards the goaf:

$$q_{CO\ 9-10} = c_{9-10} \cdot Q_{9-10} \cdot 10^{-3}$$

resulting that: $Q_{9-10} = -4{,}35 \cdot 10^{3} /211 = -20{,}6$ m^3/min

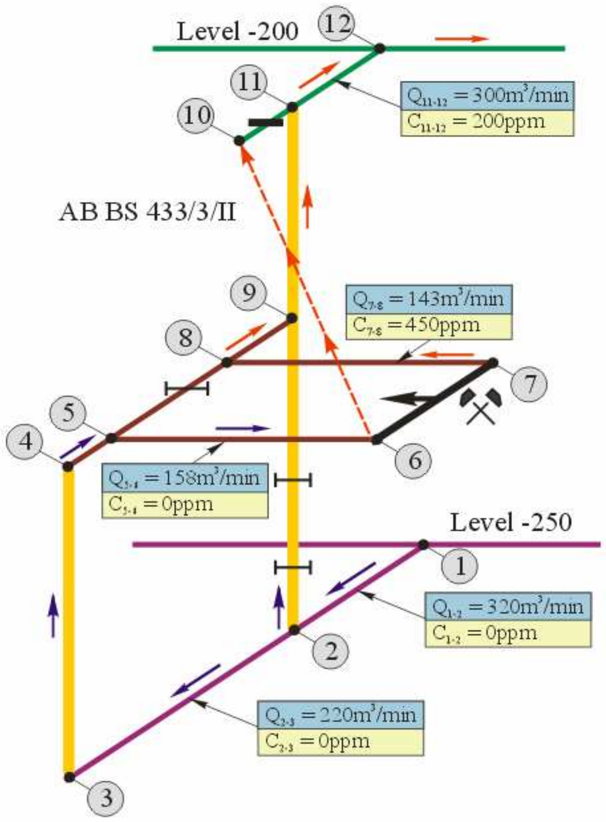

Figure 1. Coal bed B.S. no. 433/3/II from Petrila Mining Unit

3.2. Absolute carbon oxide flow applied to the undermined coal bed no. 434E/3/II from Petrila Mining Unit

In case of the undermined coal bed no. 434 E/3/II from Petrila Mining Unit, Fig.2, we obtain the following results:

- at the level of the floor directional gallery, branch 8-9, the absolute carbon oxide flow has been: $q_{CO\ 8-9} = 190 \cdot 200 \cdot 10^{-3} = 38$ L/min CO

- at the level of the transversal sub-layer gallery over the floor, branch 9-10, by applying Kirchhoff's first law in junction 9, we will have:

$$c_{8-9} \cdot Q_{8-9} \cdot 10^{-3} + c_{6-9} \cdot Q_{6-9} \cdot 10^{-3} = c_{9-10} \cdot Q_{9-10} \cdot 10^{-3}$$

in the case in which $c_{6-9} = 0$, then: $c_{9-10} = c_{8-9} \cdot Q_{8-9}/Q_{9-10}$, so, the carbon oxide concentration has been: $c_{9-10} = 200 \cdot 190 / 190 = 200$ ppm CO

- at he the level of the rising from the floor, branch 10-13, by applying Kirchhoff's first law in junction 10, we have:

$$c_{9-10} \cdot Q_{9-10} \cdot 10^{-3} + c_{3-10} \cdot Q_{3-10} \cdot 10^{-3} = c_{10-12} \cdot Q_{10-12} \cdot 10^{-3}$$

when $c_{3-10} = 0$, results that: $c_{10-12} = c_{9-10} \cdot Q_{9-10}/Q_{10-12}$, so, the concentration of carbon oxide has been: $c_{10-12} = 200 \cdot 190 / 310 = 122$ ppm CO

- at the level of the transversal head gallery, branch 12-26, the absolute carbon oxide flow has been: $q_{CO\ 12-26} = 320 \cdot 160 \cdot 10^{-3} = 51{,}2$ L/min CO

- at the level of the transversal head gallery, branch 11-12, by applying the Continuity law, respectively Kirchhoff's first law in junction 12, we have the balance of the flows:

$$q_{CO\ 11-12} + q_{CO\ 10-12} = q_{CO\ 12-26}$$

but: $q_{CO\ 11-12} = c_{11-12} \cdot Q_{11-12} \cdot 10^{-3}$ by substituting this formula in the balance of the flows formula, it results that:

$$c_{11-12} \cdot (Q_{12-26} - Q_{10-12}) \cdot 10^{-3} = q_{CO\ 12-26} - q_{CO\ 10-12}$$

so, we will have: $c_{11-12} = (51{,}2 - 38) \cdot 10^{3}/(320 - 310) = 1320$ ppm CO

Knowing the CO concentration, we can determine the circulated air flow through the goaf:

$$Q_{11-12} = q_{CO\ 11-12} \cdot 10^{3}/c_{11-12},$$

but $q_{CO\ 11-12} = q_{CO\ 12-26} - q_{CO\ 10-12} = 13{,}2$ L/min CO, so $Q_{11-12} = 13{,}2 \cdot 10^{3}/1320 = 10$ m^3/min

It results that 10 m^3/min enters into the return air exhaust circuit through the insulation construction located on the branch 11-12.

3.3. Absolute carbon oxide flow applied to the undermined coal bed no. 434V/3/II from Petrila Mining Unit.

The undermined coal bed no. 434 V/3/II has been put under general depressure in order to re-open it. As a consequence, the circulated air flows, respectively the gas concentrations are not specific for the current works in normal conditions, but they are specific for a special transitory time period over which the activities have been developed under the protection of rescue apparat.

In case of the undermined coal bed no. 434 V/3/II from Petrila Mining Unit, Fig.2, we obtain the following results: $q_{CO\ 20\text{-}21} = 40 \cdot 20 \cdot 10^{-3} = 0{,}8$ L/min CO

- at the level of the transversal sub-layer gallery over the floor, branch 21-22, by applying Kirchhoff's first law in junction 21, we will have:

$$C_{20\text{-}21} \cdot Q_{20\text{-}21} \cdot 10^{-3} + c_{18\text{-}21} \cdot Q_{18\text{-}21} \cdot 10^{-3} = c_{21\text{-}22} \cdot Q_{21\text{-}22} \cdot 10^{-3}$$

in the case in which $c_{18\text{-}21} = 0$, the carbon oxide concentration has been: $c_{21\text{-}22} = 20 \cdot 40/40 = 20$ ppm CO

- at he the level of the rising from the floor, branch 22-24, by applying Kirchhoff's first law in junction 22, we have:

$$C_{21\text{-}22} \cdot Q_{21\text{-}22} \cdot 10^{-3} + c_{15\text{-}22} \cdot Q_{15\text{-}22} \cdot 10^{-3} = c_{22\text{-}24} \cdot Q_{22\text{-}24} \cdot 10^{-3}$$

in the case in which $c_{15\text{-}22} = 0$, then the carbon oxide concentration has been $c_{22\text{-}24} = 20 \cdot 40/100 = 8$ ppm CO

- at the level of the transversal head gallery, branch 24-25, the absolute carbon oxide flow has been: $q_{CO\ 24\text{-}25} = 8 \cdot 100 \cdot 10^{-3} = 0{,}8$ L/min CO

- at the level of the closed transversal head gallery, branch 23-24, by applying the Continuity law, respectively Kirchhoff's first law in junction 24, we have the balance of the flows:

$$q_{CO\ 23\text{-}24} + q_{CO\ 22\text{-}24} = q_{CO\ 24\text{-}25}$$

but: $q_{CO\ 22\text{-}24} = 8 \cdot 100 \cdot 10^{-3} = 0{,}8$ L/min CO, so: $q_{CO\ 23\text{-}24} = 0{,}8 - 0{,}8\ m^3 = 0$ L/min

It results that over the branch 23-24, there is no air flow.

3.4. Absolute carbon oxide flow applied to the sealed undermined coal bed no. 434E/3/II from Petrila Mining Unit

In case of the sealed undermined coal bed no. 434E/3/II from Petrila Mining Unit, Fig.3 we obtain the following results:

- at the level of the transversal sub-layer gallery over the floor, branch 9-10, by applying Kirchhoff's first law in junction 10, we will have:

$$c_{9\text{-}10} \cdot Q_{9\text{-}10} \cdot 10^{-3} + c_{3\text{-}10} \cdot Q_{3\text{-}10} \cdot 10^{-3} = c_{10\text{-}12} \cdot Q_{10\text{-}12} \cdot 10^{-3}$$

in the case in which $c_{3\text{-}10} = 0$, the carbon oxide concentration has been: $Q_{9\text{-}10} = 140 \cdot 142/4000 = 5 m^3/min$

Now, we can calculate the CO absolute flow over the branch 9-10.

$$q_{CO\ 9\text{-}10} = 4000 \cdot 5 \cdot 10^{-3} = 20 \text{ L/min CO}$$

- at the level of the transversal head gallery, branch 12-26, the absolute carbon oxide flow has been: $q_{CO\ 12\text{-}26} = 150 \cdot 160 \cdot 10^{-3} = 24$ L/min CO

- at the level of the transversal head gallery, branch 11-12, by applying the Continuity law, respectively Kirchhoff's first law in junction 12, we have the balance of the flows:

$$q_{CO\ 11\text{-}12} + q_{CO\ 10\text{-}12} = q_{CO\ 12\text{-}26}$$

but: $q_{CO\ 11\text{-}12} = c_{11\text{-}12} \cdot Q_{11\text{-}12} \cdot 10^{-3}$
$Q_{11\text{-}12} = Q_{12\text{-}26} - Q_{10\text{-}12}$

by substituting, it results that:

$$c_{11\text{-}12} \cdot (Q_{12\text{-}26} - Q_{10\text{-}12}) \cdot 10^{-3} = q_{CO\ 12\text{-}26} - q_{CO\ 10\text{-}12}$$

from where it results that:

$$c_{11\text{-}12} = (q_{CO\ 12\text{-}26} - q_{CO\ 10\text{-}12}) \cdot 10^{3} / (Q_{12\text{-}26} - Q_{10\text{-}12})$$

so that we have:

$$c_{11\text{-}12} = (24 - 20) \cdot 10^{3} / (160 - 147) = 308 \text{ ppm CO}$$

Knowing the CO concentration we can determine the circulated air through the goaf:

$$Q_{11\text{-}12} = q_{CO\ 11\text{-}12} \cdot 10^{3}\ \ c_{11\text{-}12}$$

but: $q_{CO\ 11\text{-}12} = q_{CO\ 12\text{-}26} - q_{CO\ 10\text{-}12} = 4$ L/min CO, so: $Q_{11\text{-}12} = 4 \cdot 10^3/308 = 13\ m^3/min$

It results that 5 m^3/min enter into the return air exhaust circuit through the insulation construction located on the branch 9-10, and 13 m^3 / min enter into the return air exhaust circuit through the insulation construction located on the branch 11-12.

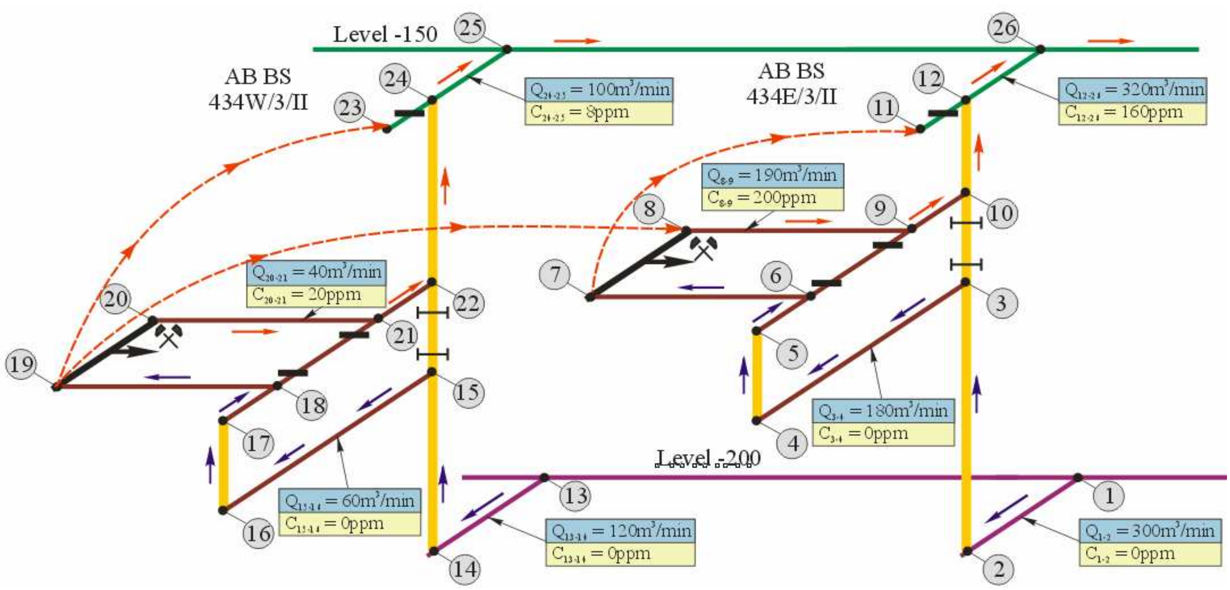

Figure 2. Coal bed no. 434 E/3/II from Petrila Mining Unit

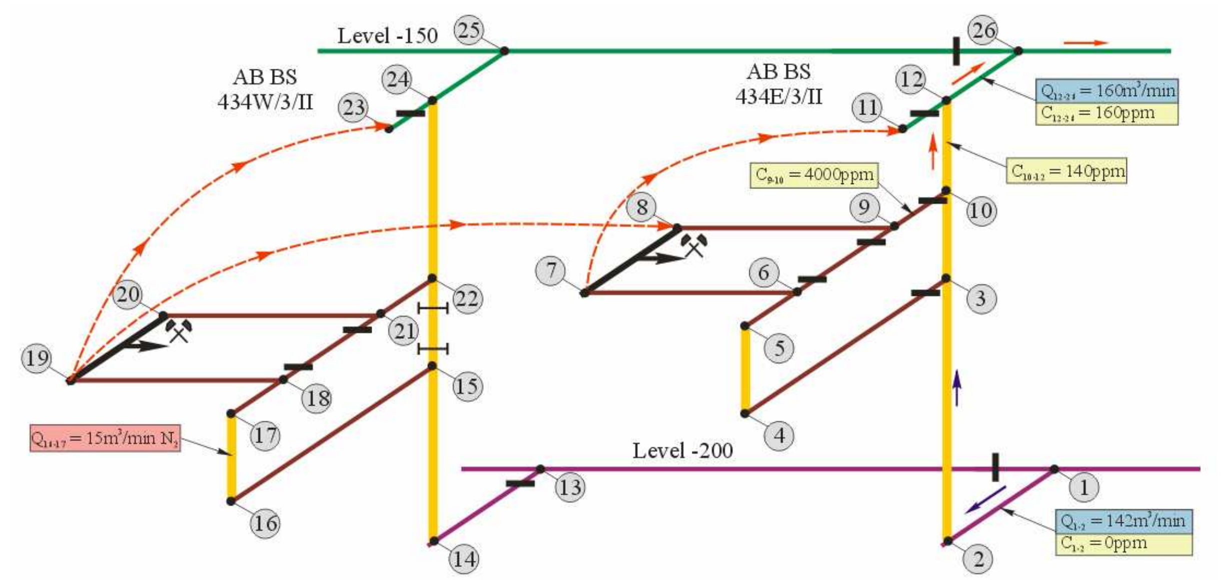

Figure 3. Coal bed no. 434 E/3/II from Petrila Mining Unit

4. Conclusions

An important technical problem for the management of the ventilation networks is represented by the flows which are lost through goafs.

The methods for the determination of flow losses through goafs are of quantitative and qualitative type.

One of the quantitative methods for the determination of flow losses through goafs is the one which uses the absolute carbon oxide flow.

The method can be used in every underground mining unit where carbon oxide resulted from the oxidation process occurs.

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