DETERMINATION OF AERODYNAMIC PARAMETERS SPECIFIC TO THE GOAF

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Abstract: *When underground coal mining activities are involved, the occupational safety and health conditions depend mainly on the management of the ventilation network. An important component of the coordination of the ventilation networks is the flows lost through the goaf. The methods for determining the flow losses through the goaf are of qualitative and quantitative type. In order to establish the specific parameters of the goaf, INCD - INSEMEX Petroşani carried out detailed researches, measurements and experiments at the level of some stopes belonging to the mining operations from the Jiu Valley. The paper presents the critical flow index –* I_{CD}*, the permeability index –* I_P *and the critical slope index* I_{CP}*.*

Key words: *critical flow index, permeability index, critical slope index, aerodynamic parameters, air losses*

Mining Revue – important publication for disseminating the results of research conducted for increasing the OHS level in the mining industry

INSEMEX Petroșani was founded in 1949 under the name of "Research Station for Mining Safety - SCSM", as a subsidiary of the Institute of Mining Research - ICEMIN Bucharest, its establishment being determined by the need to solve safety problems in the Romanian mining industry. When choosing the location, the importance of the Jiu Valley mining basin and the multiple mining security issues it raised were taken into account.

The main concerns of researchers in the first five-year existence of SCSM were oriented towards the mines in the coal basins of the Jiu Valley and Banat, with studies on explosive characteristics of coal dust and homologation of explosion-proof electrical equipment manufactured in the country, but since 1956 its area of activity greatly expanded, by covering the metalliferous, non-metalliferous and energetic sectors. This eventually led to the separation from ICEMIN and its reorganization in 1965 as an independent research institute, with working conditions corresponding to an institute with multiple concerns, according to the requirements of the developing mining industry. Carrying successively several names influenced by the national political-administrative situation, since 2006 the research unit operates as a National Institute for Research - Development in Mining Safety and Protection to Explosion - INSEMEX, with the status of national authority.

Access to information disseminated by academics, researchers and experts from the country and abroad in journals and specialized books has been the basis for the development of technical considerations developed over time by INSEMEX researchers who have actively contributed to achieving better results in the field of mining. In this sense, Mining Revue has represented since its first issue a source of technical-scientific information extremely important for INSEMEX researchers, presenting results of studies and experiments worldwide.

During its 70 years of existence, Mining Revue has continuously improved its standards and currently has some of the highest expectations concerning the quality and impact of articles, publishing quarterly some of the most important results of innovative research in the field of mineral exploitation, from the country and from abroad. The revue covers key issues faced by the mining industry and provides solutions based on fundamental and applied studies and research involving the development of new scientific methods.

The editorial staff of Mining Revue and the reviewers who are recognized experts in the fields covered by the revue provide all the prerequisites for maintaining a high standard of publication. Of course, the success of the journal depends not only on them, but also on readers and authors who constantly contribute with valuable and up-to-date scientific information and articles.

On the occasion of the 70th anniversary, we express our gratitude to all those who have contributed to the constant improvement of the Mining Revue over the years and we are sure that it will continue to prove to be a very useful tool in the future which to support the work of researchers with concerns in the field of Occupational Health and Safety in the extractive industries.

„Happy 70th Anniversary !"

Team of Researchers
INCD INSEMEX Petroșani

1. Introduction

Mining ventilation is an extremely sensitive and complex field that encompasses a multitude of disciplines put at the service of achieving and maintaining underground safety conditions. (Băltăreţu, R., Teodorescu, C., 1971; Covaci, S., 1983; Patterson, A., M., 1992; Todorescu, C., Gontean, Z., Neag I., 1980).

In this sense, solving the ventilation networks with the help of the calculation technique represents a huge step forward that allows the practitioners to visualize in real time the changes in the network and what is even more important, they can anticipate possible disturbances in the ventilation system.

Also, the flow losses at the goaf level can be determined quantitatively.

2. Critical flow index – I_{CD}

In order to determine the preparation stage of the goaf in relation to the danger of spontaneous combustion, the "critical flow index -I_{CD}" can be used. Critical flow index – I_{CD}, represents the flow of air circulated per unit area, at the level of the goaf (Cioclea, D., 2001; Cioclea, D., 2008; Cioclea, D., 2010-2011; Matei, I., Toth, I., Cioclea, D., ș.a., 2003; Matei, I., Cioclea, D., Toth, I., ș.a., 2004).

This index is calculated according to the lost air flows determined directly or indirectly.

$$I_{CD} = Qse/S \quad (m^3/min \cdot m^2) \tag{1}$$

Qse - the flow of air circulated at the level of the goaf (m^3/min).

S - goaf section (m^2)

Depending on the critical flow index, the exploited space can be characterized by 5 domains, namely:

A. Non-hazardous area

$$0 \leq I_{CD} < 0{,}1 \tag{2}$$

This field is characterized by the lack of risk of spontaneous combustion at the level of the goaf.

B. Pre-critical area

$$0{,}1 \leq I_{CD} < 0{,}4 \tag{3}$$

This field is characterized by the increased risk of spontaneous combustion phenomena at the level of the goaf.

Any increase in flow leads the goaf to the critical area.

C. Critical area

$$0{,}4 \leq I_{CD} < 0{,}6 \tag{4}$$

This field is characterized by the imminent risk of spontaneous combustion phenomena at the level of the goaf

D. Post-critical area

$$0{,}6 \leq I_{CD} < 0{,}9 \tag{5}$$

This area is characterized by the increased risk of spontaneous combustion at the level of the goaf and is specific to the conditions in which the insulation constructions are incorrectly executed and have a high degree of permeability.

E. Area not allowed

$$I_{CD} \geq 0{,}9 \tag{6}$$

This field presupposes aerodynamic paths on which high flows are circulated, specific to the unclosed goafs, which contradicts the legislation in force.

3. Permeability index – I_P

In order to determine the permeability degree of the goaf in relation to the danger of spontaneous combustion, the "permeability index – I_P" can be used.

The permeability index - I_p, represents the resistance opposed by the goaf to the air flow. This index is calculated according to the pressure loss required to convey the lost air flow, determined by in situ measurements.

$$I_P = 3600 \cdot H / S^2 \cdot I^2_{CD} \quad (N.s^2/m^6) \tag{7}$$

where:

H - the total depression exerted at the level of the goaf– N/m^2;

S - section of the goaf at the stope level - m^2;

I_{CD} - the critical flow index - m^3/min - m^2

Depending on the permeability index, the exploited space can be characterized by 5 domains, namely:

A. Very hard permeable area

$$I_P \geq 360 \cdot 103 \cdot H/S^2 \tag{8}$$

This area is characterized by a very tight goaf, respectively by the lack of the risk of spontaneous combustion phenomena.

B. Permeable area

$$360 \cdot 10^3 \cdot H/S^2 > IP \geq 22{,}5 \cdot 10^3 \cdot H/S^2 \quad (9)$$

This field is characterized by a tightly goaf, respectively the increased risk of spontaneous combustion phenomena at the level of the goaf.

Any increase in permeability leads the goaf to the critical area.

C. Critical permeability area

$$22{,}5 \cdot 10^3 \cdot H/S^2 > I_P \geq 10 \cdot 10^3 \cdot H/S^2 \quad (10)$$

This field is characterized by a goaf with critical sealing, respectively by the imminent risk of the occurrence of spontaneous combustion phenomena at the level of the goaf.

D. Very permeable area

$$10 \cdot 10^3 \cdot H/S^2 > I_P \geq 4{,}5 \cdot 10^3 \cdot H/S^2 \quad (11)$$

This area is characterized by a goaf with very weak sealing and by the increased risk of spontaneous combustion phenomena and is specific to the conditions in which the insulation constructions are incorrectly executed and have a high degree of permeability.

E. Area not allowed

$$I_P \leq 4{,}5 \cdot 10^3 \cdot H/S^2 \quad (12)$$

This area is characterized by a goaf with extremely poor sealing. This field presupposes aerodynamic routes on which high flows are circulated, specific to the unclosed goafs, which contradicts the legislation in force.

4. Determination of the aerodynamic parameters specific to the goaf at a stope level

According to fig. no. 1, the balance of airflows at B_{NAR} stope level, at frontal stope, the number level was:

$$B_{NAR} = 12{,}5 \text{ m3/min} = 0{,}208 \text{ m}^3/\text{s}$$

The depression required for the airflow through the exploited space Hse, is equal to the pressure loss required for the airflow on the active works from the point of entry of the air into the stope until after the isolation dam corresponding to the number 2N as follows:

$$Hse = 220 \quad (Pa)$$

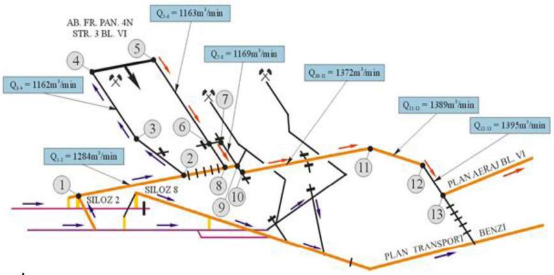

Fig. 1 *Mine workings adjacent to stope*

Specific resistance of the stope Rse is
$Rse = Hse / Qse^2$
so
$Rse = 220/0{,}2082 = 5.085{,}059$ (Ns^2/m^8)

Critical flow index - I_{CD} at:
$I_{CD} = 12.5/ 520 = 0{,}024$ $(m^3/min \cdot m^2)$

Depending on the critical flow index -I_{CD}, the goaf falls into area A - the non-hazardous area.

Permeability index – I_P was:
$I_P = 3600/ 0{,}0242 \cdot H/S2 = 6250 \cdot 10^3 \cdot H/S^2$
$I_P = 220 \cdot 3600/270.400 \cdot 0{,}0242 = 5085{,}0587$ $(N.s^2/m^6)$

Depending on the permeability index - IP, the goaf falls in area A, a very hard permeable area.

5. Air loss modelling at a stope level

In order to model the ventilation networks for the purpose of quantitative assessment of air losses, by using the 3D CANVENT program, it is necessary to make the ventilation scheme for a subcircuit or circuit based on topographic coordinates. (Gherghe I., Cioclea D., ș.a., 2018; Rădoi, F., Cioclea D., ș.a., 2018; Todorescu, C., Gontean Z., Neag I., 2000) .

These can be chosen at random or real data related to a subcircuit or a real circuit can be entered, fig. 2.

Figure 2. shows a stope based on geodetic coordinates. Also, the flows at the stope level 383 m^3 / min, respectively at the working sub-level of 327 m^3 / min are real.

For exemplification, it was used the situation in which at the level of number of stopes there are no flow losses, respectively the aerodynamic resistance of the goaf is specific to a stope, namely 280 Ns^2 / m^8. The aerodynamic resistance of the goaf is thus distributed 200 Ns^2 / m^8 for the insulation work and 80 Ns^2 / m^8 for the goaf.

The depression used for modelling is 50 Pa and is equal to the sum of the pressure losses at the level of the branches that form the ventilation path of the stope.

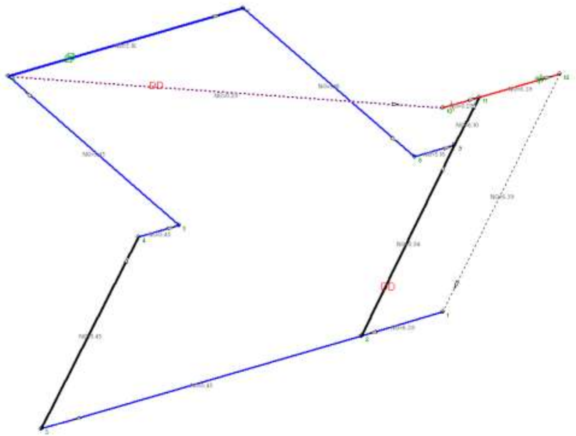

Fig. 2 *Stope modelling*

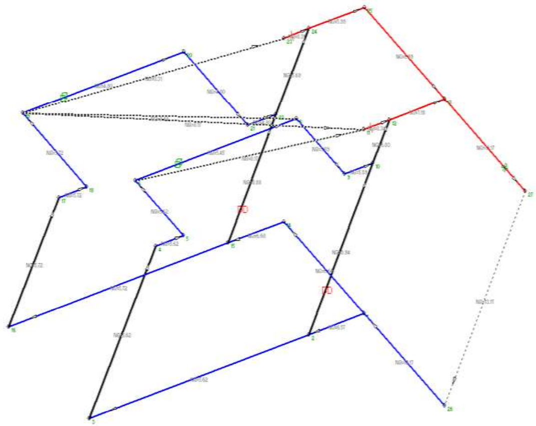

Fig. 3 *Modelling of two successive stopes*

Following the modelling with the help of the 3D CANVENT program, the real distribution of the air flows at the level of each branch is obtained. In this sense we have:

- On the supply route of the stope ramification 1-2 the air flow is 6,39 m^3/s;
- On the supply route of sub-level ramifications 2-3; 3-4; 4-5; 5-6, airflow is 5,45 m^3/s;
- At the stope level on the exhaustion path of the vicious air ramifications 6-7; 7-8; 8-9, the air flow is 5,16 m^3/s;
- The airflow at the shorting raise level ramification 2-9the airflow is 0,94 m^3/s;
- The airflow at the level of the raise exhaustion path ramification 9-11, the airflow is 6,10 m^3/s;
- On the exhaustion path of the stope ramification 11-12, the airflow is 6,39 m^3/s;

On the lost airflow through goaf ramifications 5-10; 10-11, the airflow is 0,29 m^3/s.

6. Modelling of air losses at the level of two successive stopes

In case of the exploitation of thick layers of high inclination by applying the method of exploitation with undermined coal bank and successive sub-levels, the aspects related to the analysis of air losses through the goaf are much more complicated. (Cioclea, D., Toth, I., ș.a., 2006; Cioclea, D., Toth, I., ș.a., 2006; Cioclea,D., Toth, I., ș.a., 2009).

The complexity consists in the fact that we have two adjacent and successive stopes that involve the interconnection of the goaf related to the stopes.

Figure 3 shows an example of two adjacent and successive undermined coal bank abutments showing the common and interconnected exploited space based on geodetic coordinates.

Also, the flow at the level of the stopes ensemble was of 13.16 m3 / s, respectively at the level of the working sub-levels of 5.62 m3 / s and 5.71 m3 / s, respectively.

For exemplification, it was used the situation in which at the level of the two stopes there are no flow losses, respectively the aerodynamic resistance of the goaf is specific to a stope, namely 280 Ns^2 / m^8.

The aerodynamic resistance of the goaf is distributed as follows: 200 Ns2 / m8 for the insulation works and proportionally with 80 Ns2 / m8 for the goaf.

The depression used for modelling is 62 Pa and is equal to the sum of the pressure losses at the level of the branches that form the ventilation path of a stope.

Following the modelling with the help of the 3D CANVENT program, the real distribution of the air flows at the level of each branch is obtained. In this sense we have:

- On the supply route of the stopes assembly ramification 26-1 the airflow is 13,16 m^3/s;
- On the supply route of the stope no 1 ramification 1-2 the airflow is 6,56 m^3/s;
- On the supply route of the stope no 2 ramification 14-15 the airflow is 6,60 m^3/s;
- On the supply route of the sub-level corresponding to stope no 1 ramifications 2-3; 3-4; 4-5; 5-6, the airflow is 5,62 m^3/s;
- On the supply route of the sub-level corresponding to stope no 2 ramifications 15-16; 16-17; 17-18; 18-19, the airflow is 5,71 m^3/s;
- At the no 1 stope level, respectively on the exhaustion path of the vicious air, ramifications 6-8; 8-9; 9-10, the airflow is 5,89 m^3/s;
- At the no 2 stope level, respectively on the exhaustion path of the vicious air, ramifications 19-20; 20-21; 21-22, the airflow is 4,80 m^3/s;
- The airflow at the no 1 raise level on shorting, ramification 2-10, the airflow is 0,94 m^3/s;
- The airflow at the no 2 raise level on shorting, ramification 15-22, the airflow is 0,88 m^3/s;
- The airflow at the no 1 raise level on exhaustion path ramification 10-12, the airflow is 6,83 m^3/s;

- The airflow at the no 2 raise level on exhaustion path ramification 22-24, the airflow is 5,69 m^3/s;
- On the exhaust pathway of stope no. 1, branch 12-13, the air flow is 7,18 m^3/s;
- On the exhaustion path of the no 2 stope ramification 24-25, the airflow is 5,98 m^3/s;
- On the exhaustion path of the stopes assembly ramification 13-27, the airflow is 13,16 m^3/s;
- The air loss flow through the goaf adjacent to no 2 stope ramification 6-11; 11-12, the airflow is 0,17 m^3/s;
- The air loss flow through the goaf adjacent to no 2 stope ramification 19-23; 23-24, the airflow is 0,30 m^3/s;
- The air loss flow through the goaf interconnected ramification 19-8, the airflow is 0,45 m^3/s;
- The air loss flow through the goaf adjacent to stopes no1 and no 2 ramifications 19-11; 11-12, the airflow is 0,17 m^3/s.

The total real flow lost on all directions at the level of the goaf afferent to the stope no. 2 is 1.09 m^3/s.

The unfavourable situation is generated by the fact that 0.92 m^3 / s is manifested at the level of stope no.2 and 0.34 m^3 / s is manifested at the level of stope no.1 (0.17 m^3 / s is manifested at the level of both stopes).

The I_{CD} index at the level of the two stopes in the conditions, in which the length of the front is of 40m, is:

- at the no 1 stope level

I_{CD}=55,2/100=0,55 $m^3/min \cdot m^2$

Depending on the critical flow index – I_{CD}, the goaf falls into area C. critical area.

- at the no 2 stope level

I_{CD}=20,4/100=0,20 $m^3/min \cdot m^2$

Depending on the critical flow index – I_{CD}, the goaf falls into area B. pre critical area.

7. Modelling air losses by inducing additional resistances

The method consists in the virtual application of a voluntary, consecutive and progressive stress on the goaf, by artificially inducing a consecutively increasing resistance at the level of the directional gallery on the bed afferent to an undermining stope applied when working a thick layer with high slope in successive slices or sub-levels.

If at the level of such a stope, which is located in the first sub-level, the geodetic coordinates are obtained, respectively through a measurement campaign the depressiometric survey is performed at the level of each branch, and the obtained data are entered in the database of the 3D program CANVENT, the image of fig. no. 4 is shown, which also shows the aerodynamic connection through the goaf.

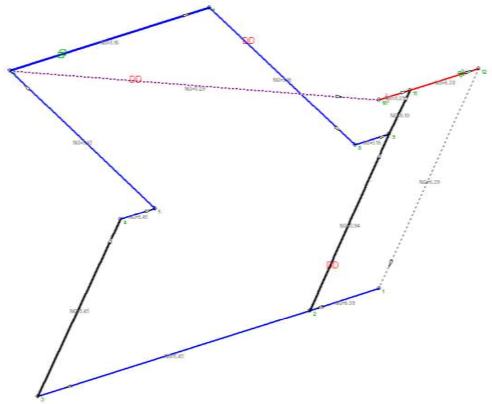

Fig. 4 *Modelling a stope with the induction of additional resistances*

Virtually, a ventilation door is placed at the level of the directional gallery on the bed, the resistance of which is progressively varied from 0 to 5 Ns^2 / m^8. At each change of the aerodynamic resistance, the flow lost through the goaf and the depression exerted on it corresponding to the lost flow is noted (Cioclea, D., 2006).

If the respective parameters, Q and H are transposed in a graph of type H = f (Q), a curve results which by linearization will lead to a straight line, fig. 5.

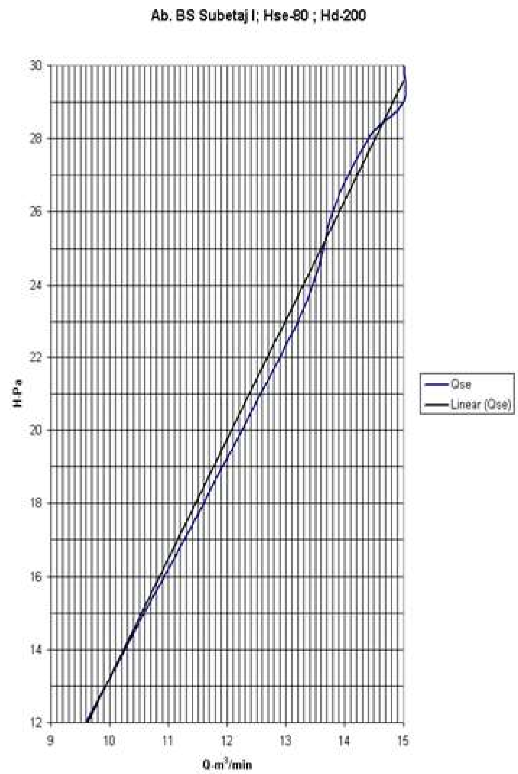

Fig. 5 *Determination of the slope index*

Depending on the structure of the stope, on the distribution of the aerodynamic resistances at the branch level, on the depression exerted on the stope, on the depression exerted on the goaf, specific linearized curves result, with different inclinations.

With the help of this graph you can establish a "critical slope index I_{CP}" which can be used as a fire index.

$$I_{CP} = \text{ctg}\ \alpha \quad (13)$$

$$\text{ctg}\ \alpha = \Delta Q/\Delta H \qquad (m^5/N\cdot s) \quad (14)$$

where:
α – the angle made by the graph with the abscissa °);
ΔQ – increasing the flow lost through the goaf(m^3/min);
ΔH – the increase of depression exerted on the goaf (Pa)

The slope index represents the flow of air circulated at the level of the goaf at a depression of one Pa.

The I_P slope index, in order to be used as a fire index, a correlation must be established between its different values and the danger of spontaneous combustion. In order to calibrate the slope index, a detailed analysis was performed on the stopes related to the mining operations, which took into account the aerodynamic parameters at the level of branches and the depressions and flows made at the level of stope. The diagrams regarding the air flow through the goaf were made in the conditions of using the minimum, average, and maximum values referring to the realized parameters. Following the analysis, it turned out that the ICP index is used only for undermining stopes, outlined in thick layers of high inclination having the following values and meanings:

$I_{CP} < 0{,}2 \quad (m^5/N\cdot s)$ - normal situation;
$0{,}2 \le I_{CP} \le 0{,}8 \quad (m^5/N\cdot s)$ - the appearance of the self-heating phenomenon;
$I_{CP} > 0{,}8 \quad (m^5/N\cdot s)$ - the appearance of the self-ignition phenomenon.

8. Modelling air losses at the level of a modelled and solved ventilation network

In order to determine the air losses at the level of a network, the ventilation network related to the Vulcan mine was chosen, modelled and solved.

In addition to the aerodynamic parameters specific to the ventilation network, the aerodynamic paths through the exploited space were modeled. (Cioclea, D., 2007-2009; Cioclea, D., Toth, I., ş.a., 2009; Cioclea, D., Toth, I., ş.a. 2011; Cioclea, D., Gherghe, I., ş.a., 2020; Cioclea, D., Gherghe, I., ş.a., 2020; Drăgoescu, R., Cioclea, D., ş.a., 2020; Gherghe I., Cioclea D., ş.a., 2005).

In order to obtain the air flows lost through the goaf, the calculated resistances were associated to the aerodynamic paths, namely ≈ 5000 $N\cdot s^2/m^8$.

The updated ventilation network for the Vulcan mine is shown in fig. 6.

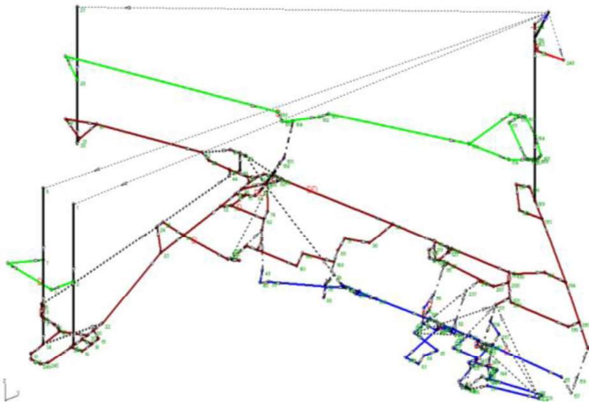

Fig. 6 *Vulcan mine ventilation network*

The following stopes are active at the level of the ventilation network: Stope no., 2 layer. 3, block VI; stope no1., 1 layer 3, block VII; stope no., 1 layer 3, block VIII; stope no., 1-4 layer 3, block VIII;

At the level of each stope, the aerodynamic connections between the fresh air entry point and one or more maximum elevation points at which the depression is manifested on the goaf were made.

In fig. no. 7 a detail is given at the level of the stope no., 2 layer 3, block VI, which also includes the aerodynamic connections made between nodes 36-102 and 36-79 respectively.

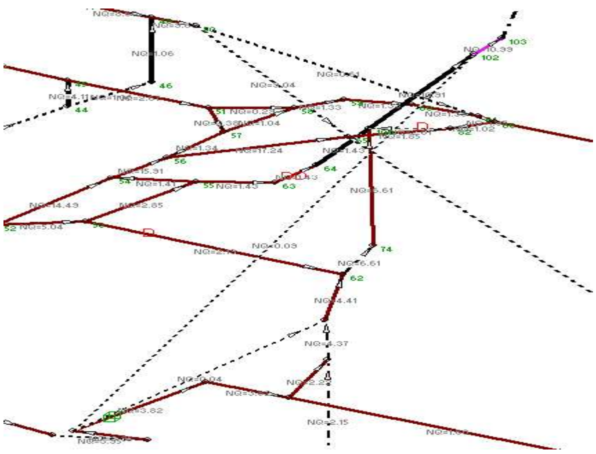

Fig. 7 *Block VI detail*

Following the modelling with the help of the 3D CANVENT program, the real distribution of the air flows at the level of each branch was obtained. In this sense we have:

- On the supply route of the stope ramification 26-21 the airflow is 3,95 m^3/s;

- On the supply route of the sub-level ramifications 21-33; 33-36, the airflow is 3,95 m^3/s;
- At the respective stope on the evacuation pathways of the vicious air ramifications 36-37; 37-38; 38-75, the airflow is 3,82 m^3/s;
- The airflow at the raise level on shorting ramification 49-75, the airflow is 2,15 m^3/s;
- The airflow at the raise level on the evacuation circuit ramification -79, ; 100-102, the airflow is4,37 m^3/s, respectively 10,91 m^3/s;
- On the exhaustion path of the stope ramification 79-62; 102-103, the airflow is 4,41 m^3/s, respectively 10,99 m^3/s;
- The airflow lost through the goaf ramifications 36-79; 36-102, the airflow is 0,04 m^3/s, respectively 0,09 m^3/s in total 0,13 m^3/s.

In fig. 8 a detail is shown at the sub-level stopes no. 1 layer. 3, block VII, no., 1 layer. 3, block VIII and no., 1-4 layer. 3, block VIII, which also includes the aerodynamic connections made both between nodes belonging to the same stope and between nodes belonging to the adjacent stopes.

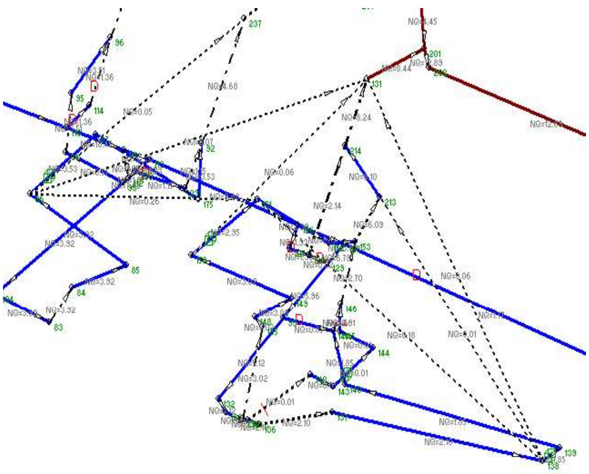

Fig. 8 *Detaliu blocurile VII – VIII*

Following the modelling with the help of the 3D CANVENT program, the real distribution of the air flows at the level of each branch was obtained. In this sense we have:

- on the supply route of the stope assembly ramification 110-111 the airflow is 18,45 m^3/s;
- on the supply route of the stope no 1/3/VII, ramification 204-83 the airflow is 3,92 m^3/s;
- on the supply route of the stope no 1/3/VIII, ramification 134-135 the airflow is 3,02 m^3/s;
- on the supply route of the stope no 1-4/3/VIII, ramification 101-136 the airflow is 2,09 m^3/s;
- on the supply route of the sub-level related to stope no 1/3/VII, ramifications 84-85; 85-86, the airflow is 3,92 m^3/s;
- on the supply route of the sub-level related to stope no 1/3/VIII ramifications 148-149; 149-150, the airflow is 3,02 m^3/s;
- on the supply route of the sub-level related to stope no 1-4/3/VIII, ramifications136-137; 137-138, the airflow is 2,09 m^3/s;
- on the stope level no 1/3/VII, respectively on the exhaustion pathway of the vicious ramifications 86-87; 87-175; 175-192, the airflow is 3,53 m^3/s;
- on the stope level no 1/3/VIII, respectively on the exhaustion pathway of the vicious ramifications 150-151, the airflow is 2,96 m^3/s;
- on the stope level no 1/3/VIII, respectively on the exhaustion pathway of the vicious ramifications 151-152; 152-153, the airflow is 3,39 m^3/s;
- on the stope level no 1-4/3/VIII respectively on the exhaustion pathway of the vicious ramifications 138-139; 139-140; 140-141, the airflow is 1,84 m^3/s;
- the airflow at the raise level no 1/3/VII, on shortcutting ramifications 231-92, the airflow is 1,15 m^3/s;
- the airflow at the raise level no 1/3/VIII, on shortcutting ramifications 146-153, the airflow is 2,70 m^3/s;
- the airflow at the raise level no. 1-4/3/VIII, on shortcutting ramifications 141-146, the airflow is 2,69 m^3/s;
- on the exhaustion path of the stope no 1/3/VII, ramification 215-207, the airflow is 4,74 m^3/s;
- on the exhaustion path of the stope no 1/3/VIII and no 1-4/3/VIII, ramification 131-201, the airflow is 8,44 m^3/s;
- the airflow lost through the goaf related to stope no 1/3/VII, ramification 86-237, the airflow is 0,05 m^3/s;
- the airflow lost through the goaf related to stope no 1/3/VII to stope no 1/3/VIII, ramification 86-131, the airflow is 0,07 m^3/s;
- the airflow lost through the goaf related to stope no 1/3/VIII ramification 150-131, the airflow is 0,06 m^3/s;
- the airflow lost through the goaf related to stope no 1-4/3/VIII, ramification 138-131; 138-213, the airflow is 0,06 m^3/s respectively 0,01 m^3/s;
- the airflow lost through the goaf interconnected related to stopes no 1/3/VII and 1/3/VIII ramification 86-151, the airflow is 0,26 m^3/s;
- the airflow lost through the goaf interconnected related to stopes no 1/3/VIII and 1-4/3/VIII ramification 138-151, the airflow is 0,18 m^3/s;
- the airflow lost through the goaf interconnected related to stopes no 1/3/VII, ramification 86-237; 86-131;86-151, the airflow is 0,38 m^3/s;

the total airflow loss through the goaf related to the stope no 1-4/3/VIII, ramification 138-131; 138-213;138-151, the airflow is 0,25 m^3/s.

9. Conclusions

- In order to determine the preparation stage of the goaf in relation to the danger of spontaneous combustion, the "critical flow index -I_{CD}" can be used. The critical flow index – I_{CD}, represents the flow of air circulated on the surface unit, at the level of the goaf.
- In order to establish the degree of permeability of the goaf in relation to the danger of spontaneous combustion, the “permeability index – I_P” can be used. The permeability index - Ip, represents the resistance opposed by the goaf to the air flow.
- The two parameters specific to the exploited space I_{CD} and I_P, were applied in distinct situations that involved stopes from the mining operations in the Jiu Valley.
- For the quantitative evaluation of air losses through the goaf, the method of electronic modelling of the ventilation networks can be used. In this sense, it is possible to model a ventilation network with the help of the 3D CANVENT program.
- For the modelling regarding the quantitative determination of the air losses at the level of a stope, by using the 3D CANVENT program, it is necessary to make the ventilation scheme afferent to a subcircuit or circuit based on the topographic coordinates. In this sense, the depression exerted on the goaf is determined by direct measurements and its specific aerodynamic resistance is calculated.
- The modelling regarding the quantitative determination of the air losses at the level of two successive stopes outlined in thick layers of high inclination by applying the method of exploitation with undermined coal bank and successive sub-levels, implies the interconnection of the goafs afferent to the two stopes. In this sense, the depressions exerted on the goaf are determined by direct measurements and its specific aerodynamic resistances are calculated.
- The critical slope index can be used to determine the flow of air at the level of the goaf at a depression of one Pa I_{CP}, which is measured in $m_5/N \cdot s$.
- The critical slope index I_{CP}, can be used as a fire index only for undermining stopes, outlined in thick layers of high inclination.

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