

# Simulation of a low intensity explosion phenomenon (2 bars) at the level of the ventilation network relating to the Lupeni mine

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**Abstract.** In order to ensure the optimal level of occupational health and safety, a whole series of technical measures are taken for underground activities. However, in accidental situations, generated by ignoring dangerous situations or violating occupational health and safety regulations, explosion-type phenomena occur with extremely severe repercussions in terms of loss of human lives, destruction of electromechanical equipment, as well as temporary immobilization or total loss of coal reserves. The effect of an underground explosion affects the main ventilation station in relation to the distance from the explosion site, these effects can be non-destructive or destructive. This article presents a simulation of a low-intensity explosion (2 bars) in the ventilation network of the Lupeni mine, with the aim of identifying critical areas and proposing safety measures. Using the specialized ventilation network modeling and solving program - Ventsim Visual Design, the simulation highlights the propagation of the shock wave within the galleries and identifies vulnerable points. The paper provides a detailed analysis of the effects of the explosion on the general ventilation, as well as recommendations for improving the ventilation infrastructure. In paper will present the results obtained from the simulation of a small intensity explosion phenomenon (2 bars) on the ventilation network of the Lupeni mine.

## 1 Introduction

Explosions in the mining environment represent a major risk, with serious consequences for the safety of miners and mining networks. In the context of mining exploitation in Romania, the simulation of such phenomena becomes essential for risk assessment and for the implementation of prevention measures. This article presents the simulation of a low intensity explosion (2 bars) in the ventilation network of the Lupeni mine, with the aim of identifying critical areas and proposing appropriate safety measures.

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## 2 Theoretical context

Explosion in the mining environment involves the sudden release of energy, in the form of a shock wave, generating high pressures that can cause damage to ventilation networks. When an explosion-type phenomenon occurs, on the one hand, a dynamic wave is formed that develops an overpressure of 1-8 bars in the case of methane gas and 1-11 bars when coal dust is also involved, and on the other hand, a flame front that generates temperatures of over 2500 °C. In the case of coal mines, the accumulation of flammable gases such as methane increases the risk of such events. Simulating the phenomenon offers a preventive approach by analyzing the possible consequences [1,2].

## 3 Description of the Lupeni Mine

The Lupeni Mine, one of the most important mining units in the Jiu Valley, has a complex ventilation network, designed to ensure efficient ventilation of the underground mining works.

The underground mining works are ventilated under the depression of the Suito Central Main Fan Station, which is equipped with 2 (two) axial fans, VOKD 1.8, with a nominal flow rate of 5600 m<sup>3</sup>/min. [10, 13].

The circuit of the Suito Central ventilation station extends over the following horizons:

- horizon 300 - fresh air supply horizon for mining works related to str. 3, bl. IV and V;
- horizon 400 - fresh air supply horizon for mining works related to str. 3, bl. II and IV, as well as for the evacuation of polluted air for mining works related to str. 3, bl. IV and V;
- horizon 480 is the route for the evacuation of polluted air resulting from the exploitation and preparation works of str. 3, bl. IV and V;
- horizon 650 - is the route for the evacuation of polluted air resulting from the exploitation and preparation works of str. 3, bl. II.

The underground mining works that are ventilated below the depression of the main fan station, Shaft 1Est, and which is equipped with 2 (two) axial fans, VOD 3.0, with a maximum flow rate of 14400 ÷ 16200 m<sup>3</sup>/min.

The Well 1Est circuit extends to the 400 horizon, which is the exhaust horizon of the contaminated air for the mining works related to the southern frame of the ventilation network:

- The Lupeni mine had five longwalls in operation as follows:
- The longwall with undermined bench Panel no. 1, layer 3, Block II Sublevel II;
- The longwall with undermined bench Panel no. 1, layer 3, Block II Sublevel III;
- The longwall with undermined bench Panel no. 11, layer 3, Block V;
- The longwall with undermined bench Panel no. 3, layer 3, Block V;
- The longwall with mechanized complex Panel no. 2C, layer 3, Block IV;

The entry of fresh air into the underground is done through the following works:

- Ștefan shaft;
- Shaft no. 12;
- Skip shaft;
- Coastal gallery horizontal 650;
- Auxiliary shaft South.

## 4 Using VentSim Visual Advanced software

The simulation was performed using VentSim Visual Advanced software, recognized for its ability to model complex ventilation networks in mining environments [12].

Ventilation has been a primary concern in underground mines for hundreds of years, but until the introduction of computer-aided ventilation network analysis over the past 40 years, ventilation planning and modeling was largely difficult, relying on experience, assumptions, and extensive calculations.

Even when computer-aided ventilation software enabled simulations of large ventilation networks, the workflow and interpretation of results still remained accessible only to experts in the field.

VentSim Visual Advanced aims to make ventilation network simulation accessible to any mining engineer or ventilation specialist. VentSim Visual Advanced is the first easy-to-use, integrated ventilation package with graphical design for Windows with a 3D graphical interface.

This program allows the simulation of air flow, pressure propagation and analysis of the impact of an explosion in different sections of the gallery.

The program allows the visualization of 3D Solids of the ventilation paths which allows a quick assessment to verify that the dimensions or position of the mining works are correct.

VentSim Visual Advanced also allows the animation of air currents, fans and heating/cooling sources. VentSim Visual Advanced can display a large amount of data in a way that the human brain can quickly visualize and interpret.

Animated flows show the direction and relative speed of all air currents in a mine with thousands of branches. Animated fans show whether they are on or off, while dynamic coloring draws the user's attention to specific data.

## 5 Simulation of a low intensity explosion phenomenon – 2 bars

### 5.1 Establishing the structure of the ventilation network after a low-intensity explosion

To establish the structure of a ventilation network after an explosion, it is the following steps are necessary [5, 6]:

- Establishing the influence of the explosion phenomenon on the ventilation network;
- Solving the ventilation network in relation to the changes generated by the explosion.

### 5.2 Establishing the influence of the explosion phenomenon on the ventilation network

The explosion phenomenon of a gas mixture is an extremely complex physicochemical process that depends on a series of factors, namely [1, 4, 9]:

- o The volume of the explosive mixture;
- o The type of explosive gas;
- o The concentration of the explosive gas;
- o The structure of the accumulation space;
- o The flow regime of the gas mixture;
- o The existence or not of the support on the propagation path;
- o The type of initiation source, etc.

Any change in one of the influencing factors leads to a wide variation in the explosion parameters.

In order to identify the effects of an explosion, the initial conditions are first established, namely:

- ✓ The ventilation network on which the explosion simulation is performed;
- ✓ The area chosen for the explosion to take place;
- ✓ The length of the longwall;
- ✓ The section of the longwall;
- ✓ The length of the works on which the methane accumulation occurs;
- ✓ The volume of the explosive mixture;
- ✓ The concentration of the air-methane mixture;
- ✓ The initiation source;
- ✓ The explosion pressure [3].

### 5.3 Solving the ventilation network related to the Lupeni mine in relation to the location and intensity of the virtual explosion phenomenon

To carry out simulations to determine the possible effects of an explosion, the results of the explosion risk analysis was taken into account, carried out on the complex ventilation network of the Lupeni mine, a network updated using the VentSim Visual Advanced program, these areas being shown in table no. 1. [12].

**Table 1.** Critical areas in terms of explosion risk related to underground mining works related to the Lupeni mine

Nr. crt.	Mining work name	Risk of major damage	
		Estimating	Appreciation
1.	BS the longwall circuit pan. 7C/3/4	13	Very high
2.	Front longwall circuit pan. 2C/3/4	12	Very high
3.	BS the longwall circuit pan. 9/3/5	11	Very high
4.	Collector silo at the base of the bed plane 300-360-400	10	High
5.	The longwall collector silo. BS pan 9/3/5	9	High
6.	Collector rise longwall BS pan. 7C/3/4	9	High
7.	Silo circuit Horizontal skip shaft 300	8	High
8.	Horizontal inclined collector silo 400-300	6	Environment
9.	Horizontal Skip shaft silo 400	5	Environment
10.	Silo block II, on the horizontal aeration plan circuit 400-480	5	Environment

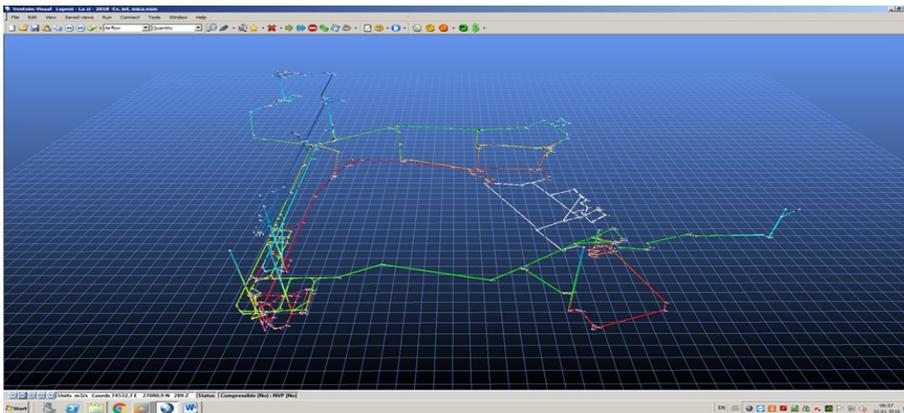
From the ten vulnerable areas obtained from the explosion risk analysis, the vulnerable area established at the level of the longwall with undermined bank 7C/3/IV, elevation 320 m, branches 374-375 [10, 11, 12] was chosen.

Following the application of the 2bar pressure gradient, at the level of the longwall whit undermined bank 7C/3/IV, elevation 320 m, branches 374-375, the area affected by the

explosion phenomenon was calculated. Thus, a number of 35 branches were affected. Also, three ventilation doors were destroyed by the shock wave of the explosion, as follows:

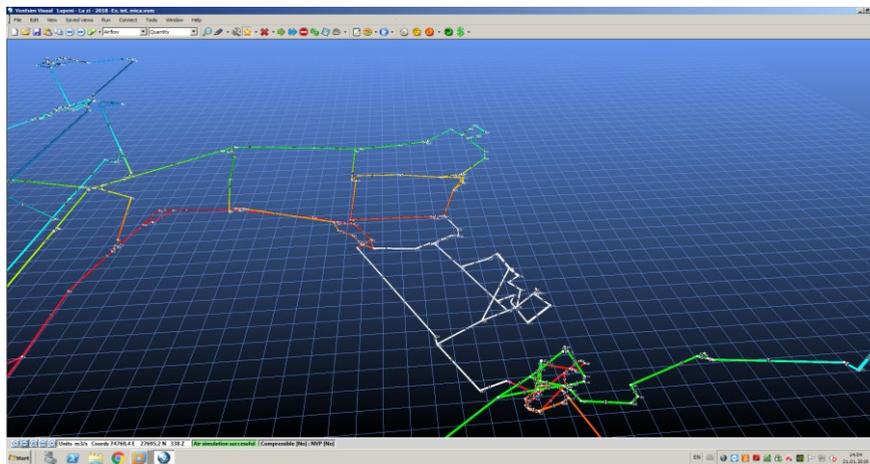
- door located on the collector shaft pan. 2C, branch 296-378;
- ventilation door located on the inclined transport plane related to the frontal longwall whit pan. 2C/3/IV, horiz. 360, branches 389-390;
- ventilation door located on the short-circuit circuit horiz. 300, bl. V, branch 318-319.

The spatial ventilation network in the 3D solid system related to the Lupeni mine, affected by a virtual explosion phenomenon of intensity equal to 2 bars, is shown in fig. 1.



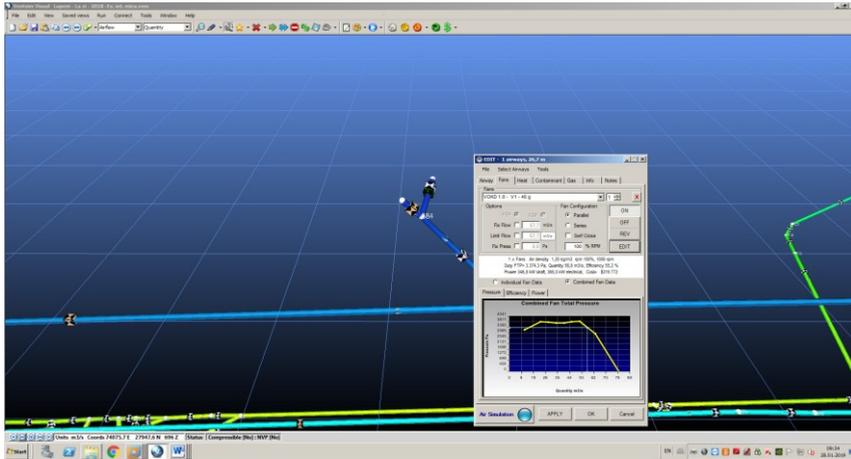
**Fig. 1.** Ventilation network affected by a 2bar explosion

Figure 2 shows the area affected by the explosion phenomenon generated virtually at the level of the longwall with the undermined bench of panel 7C/3/IV.



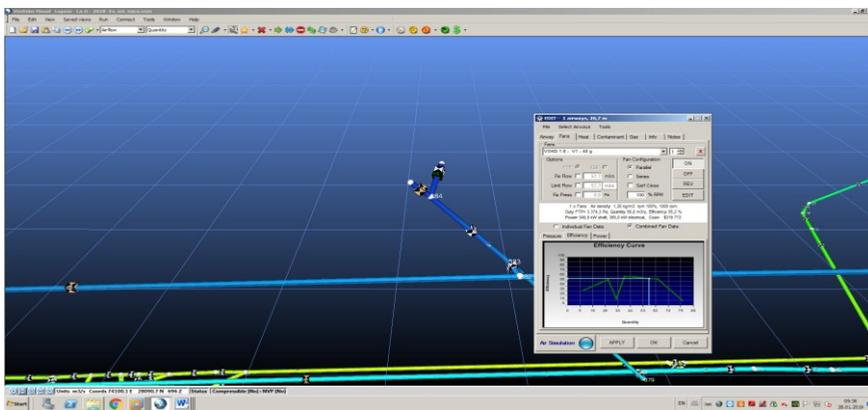
**Fig. 2.** Detail, the area affected by the 2bar explosion

The functional parameters of the active fan, respectively its characteristic curve, are shown in Figure 3

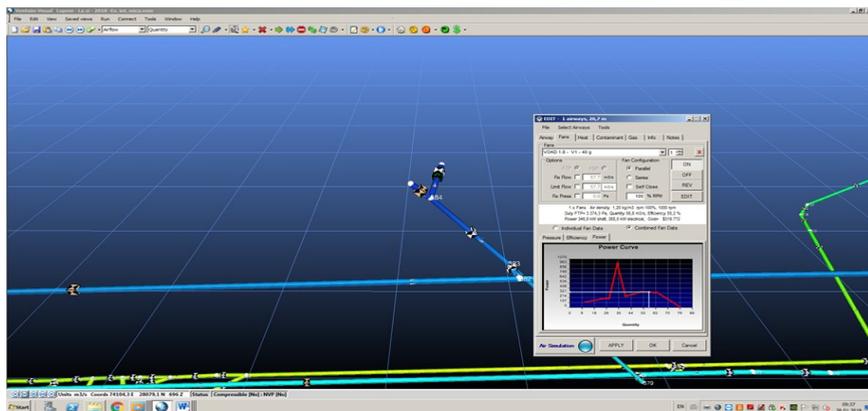


**Fig. 3.** Operating curve of the VOKD 1.8 fan, at  $\alpha=40^\circ$ , pressure-flow

In figures 4 and 5, the efficiency and power curves of the active fan are presented.

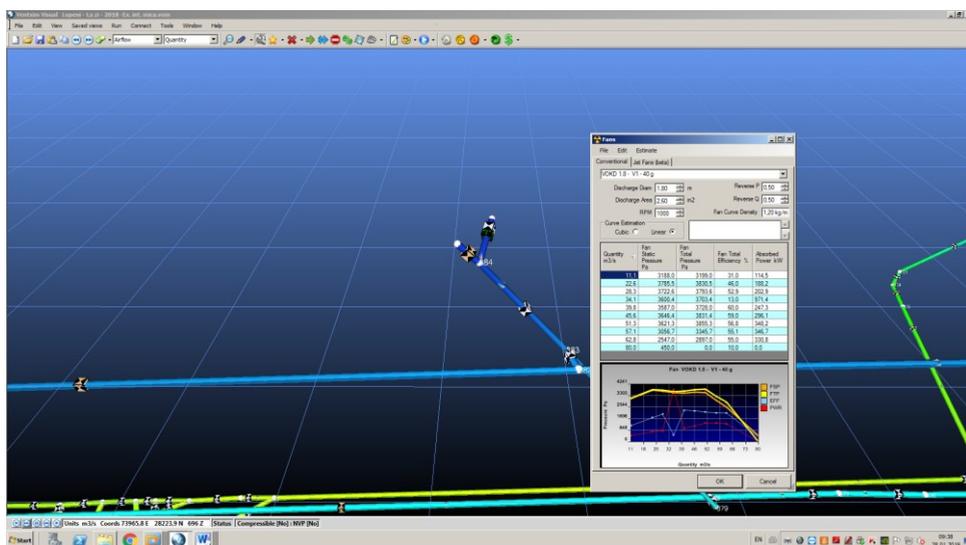


**Fig. 4.** Fan-specific efficiency curve VOKD 1,8, la  $\alpha=40^\circ$



**Fig. 5.** Fan-specific power curve VOKD 1,8, la  $\alpha=40^\circ$

The total characteristic curves specific to the active fan are shown in figure 6, where FSP - static pressure curve, in Pa, FTP - total fan pressure curve, in Pa, EFF - total fan efficiency curve, %, PWR - power curve absorbed by the active fan drive motor, in kW.



**Fig. 6.** Total characteristic curves specific to the active fan VOKD 1.8  $\alpha = 40^\circ$

The ventilation input data for the Lupeni mine are shown in Table 2.

The results obtained following the simulation of the related ventilation network the Lupeni mine, in the conditions of the production a low-intensity virtual explosion, are shown in Table 3.

**Table 2.** Input data for node coordinates specific to the ventilation network of the Lupeni mine

No	Uniqu e no	Entranc e node	Exit nod e	Mining work name	Geodetic coordinates mining work					
					X1 [m]	X2 [m]	Y1 [m]	Y2 [m]	Z1 [m]	Z2 [m]
1	2	1	2	Shaft Skip	7396 2	7396 2	2736 6	2736 6	646, 3	400
2	3	2	3	Shaft Skip	73962	73962	27366	27366	400	355, 6
3	4	2	36	Circuit shaft	73962	73948	27366	27397	400	405
4	5	36	37	Circuit shaft	73948	73946	27397	27423	405	404
5	6	37	61	Circuit shaft	73946	73946	27423	27463	404	401
6	8	41	37	Circuit shaft	73974	73946	27402	27423	404	404
7	10	36	40	Circuit shaft	73948	73961	27397	27387	405	405
8	14	3	38	horizon t 400	73962	73961	27366	27387	355,6	355
9	16	4	5	Shaft skip	73962	73962	27366	27366	280	266
10	17	5	6	Shaft skip	73962	73962	27366	27366	266	225

**Table 3.** Simulation results of the Lupeni mine ventilation network in the conditions of the production a low intensity virtual explosion - pressure 2 bars

No	Unique number	Entrance node	Exit node	Mining work name	Total air pressure [Pa]	Average air speed [m/s]	Average air flow [m <sup>3</sup> /s]	Total resistance [Ns <sup>2</sup> /m <sup>8</sup> ]
1	2	1	2	Shaft Skip	14,2	0,5	10,1	0,13793
2	3	2	3	Shaft Skip	0,6	0,3	5,1	0,02309
3	4	2	36	Circuit shaft	0,4	0,5	5	0,01616
4	5	36	37	Circuit shaft	0,3	0,4	4,5	0,01227
5	6	37	61	Circuit shaft	1,5	0,4	4,5	0,07421
6	8	41	37	Circuit shaft	0	0	0	2,3331
7	10	36	40	Circuit shaft	0,2	0	0,5	0,98407
8	14	3	38	horizont 400	0	0	0,2	0,00032
9	16	4	5	Shaft skip	0	0,2	4,5	0,00076
10	17	5	6	Shaft skip	0,2	0,1	2,9	0,01886

### 5.3. Features of Simulation in VentSim Visual Advanced:

- **Ventilation network modeling:** The Lupeni mine network was introduced into the software, including all main and secondary galleries, as well as ventilation points
- **Explosion simulation:** An initial pressure of 2 bars was applied, corresponding to the low intensity of the explosion, to observe the propagation mode of the shock wave.
- **Results analysis:** VentSim Visual Advanced provided detailed diagrams of the pressure distribution and airflow velocity at each point of the network.

## 6 Discussions

The software allowed the rapid identification of critical points and areas with a high risk of gas accumulation and the production of a low-intensity explosion - 2 bars, fig. 1-2. [ 7, 8]

Following the simulation of the virtual explosion phenomenon, of low intensity, with a pressure gradient of 2 bars, applied at the level of the longwall with the undermined bench pan. 7C/3/IV, elevation 320 m, branches 374-375, related to the ventilation network of the Lupeni mine, a reduced effect was found, locally located at the level of blocks IV and V (destruction of three ventilation doors), without transmitting major disturbances to the rest of the ventilation network, respectively at the level of the main ventilation station.

Also, in the hypothetical case of the production of a low-intensity explosion phenomenon at the longwall with the undermined bank 7C/3/IV, elevation 320 m, branches 374-375, there are risks of injury/death and risk of asphyxiation/poisoning for the working personnel located at the level of the sub-circuits of the frontal longwall no 7C and no. 2C, respectively on the gas evacuation route from the affected area.

## 7 Conclusions

This work allowed us to highlight the following findings:

1. Risk represents the characterization of an undesirable event, associated with the perception of a dangerous situation defined by through the couple of production probabilities and the severity of the consequences.
2. One of the types of risks at workplaces is represented by the risk of explosion which is part of the risk factors specific to the work environment - chemical risk factors.
3. The main measure to prevent explosions underground is to achieve appropriate ventilation to ensure the dilution of explosive gases.
4. At the level of underground mining works in relation to the combustible substance, the following types of explosions can occur: Methane explosions; Coal dust explosions; Methane gas and coal dust explosions.
5. In the event production of an underground explosion, major disturbances occur in the ventilation network generated by: partial or total destruction of adjustment doors and isolation doors, respectively of the isolation constructions. Also, collapses may occur in the mining works adjacent to the epicenter of the explosion
6. Following the explosion risk assessment operation, at the level of the ventilation network related to the Lupeni mine, a number of 10 critical areas were identified, ranging from medium to very high risk levels.
7. To establish the structure of a ventilation network after an explosion, it is the following steps are necessary:
  - Establishing the influence of the explosion phenomenon on the ventilation network;
  - Solving the ventilation network in relation to the changes generated by the explosion.
8. From the ten vulnerable areas obtained from the explosion risk analysis, the vulnerable area was choes established at the level of the longwall with the bank undermined, pan. 7C/3/IV, elevation 320 m, ramifications 374-375 was chosen.
9. Following the application of the 2bar pressure gradient, at the level the longwall with of the coal bank undermining pan. 7C/3/IV, elevation 320 m, branches 37 4-375, a number of 35 branches were affected. Also, three ventilation doors were destroyed by the shock wave of the explosion.
10. Following the simulation of the low-intensity virtual explosion phenomenon, the ventilation network was solved, obtaining the following results compared to the results obtained under the conditions of updating the ventilation network:
  - The air flow rate on the fresh air supply circuit at the horizontal level 650, 480, 400, 300, the branches with unique number 587, 267, 481, 410, 343, 115, 288, 779 remained constant, namely 55.5 m<sup>3</sup>/s.;
  - At the mine level, the branch with unique number 568, the air flow rate remained constant at the value of 55.5.;
  - At the station level, the branch with unique number 569, the air flow rate remained constant at the value of 56,8 m<sup>3</sup>/s
11. Following the simulation of the virtual explosion phenomenon, of low intensity, with a pressure gradient of 2 bars, applied at the level of the longwall with the undermined bench pan. 7C/3/IV, elevation 320 m, branches 374-375, related to the ventilation network of the Lupeni mine, a reduced effect was found, locally located at the level of blocks IV and V (destruction of three ventilation doors), without transmitting major disturbances to the rest of the ventilation network, respectively at the level of the main ventilation station.
12. Also, in the hypothetical case of the production of a low-intensity explosion phenomenon at the longwall with the undermined bench 7C/3/IV, elevation 320 m, branches 374-375, there are risks of injury/death and risk of asphyxiation/poisoning for the working personnel

located at the level of the sub-circuits of the frontal longwall no 7C and no 2C, respectively on the gas evacuation route from the affected area.

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## References

1. Bana F. - Studying the explosion mechanism of flammable environments consisting of methane and/or coal dust, in themixed with the air, in order to establish the characteristic effects, Study C.C.S.M. Petroșani, 1985
2. Barthnecht W., - Explosionen, (Springer Verlag, Berlin 1981)
3. Cioclea, D. - Hazard reduction of explosion at coal mines in the Jiu Valley through computerized management of the ventilation networks, SECTORIAL Project INSEMEX, 2010-2011.
4. Freytag H., H., - Raumexplosionen, (Herausgeber Chemie GmbH Weinheim ,1965)
5. Gherghe I, Cioclea D., et al, - Aerodynamics of Exploited Space, Vol. I, – General Technical Aspects, (INSEMEX Publishing House Petroșani, 2018)
6. Gherghe I., Analysis of ventilation networks affected by the explosion phenomenon, (INSEMEX Publishing House, Petroșani, 2020)
7. Le Roux - Notes on Mine environmental control, (The MVS of South Africa 1990)
8. Matei, I., Moraru, R, et al. - Environmental Engineering and Underground Ventilation, (Technical Publishing House București, 2000)
9. Plasche F., - Wetterlehre und brandbekämpfung im bergbau, (Fachbuchverlag Leipzig 1955)
10. Rădoi F., Cioclea D., et al, - Aerodynamics of the exploited space. Vol. II - Qualitative and quantitative analysis of air losses, (INSEMEX Publishing House Petroșani, 2018)
11. Vasilescu Gabriel-Dragoș, - Probabilistic calculation methods used in industrial risk diagnosis and forecasting, (INSEMEX Publishing House, Petroșani, 2008)
12. xxx- Program user manual VENTSIM VISUAL ADVANCED
13. xxx - Annual aeration project of the Lupeni Mine for the year 2019