

INTERLEVEL CONNECTIONS AS A WAY TO INCREASE THE VENTILATION EFFICIENCY OF A MINE VENTILATION NETWORK - A CASE STUDY

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Abstract

The exploitation of the deposit necessitates continuous optimisation of the ventilation network, as well as the need to change fans. One way of optimising the network and increasing the efficiency of ventilation may be to make interlevel connections in the form of large-diameter openings. In this study, simulation calculations were carried out by assuming the drilling of large-diameter holes and the selection of parameters for the main ventilation fans. An evaluation of the ventilation network was carried out by checking the validity of the simulation data with the actual data. The ventilation calculations showed that it is possible to increase the ventilation efficiency through the aforementioned method. The results of the calculations are presented with tabular data and simplified ventilation diagrams. The creation of at least one large-diameter opening and the upgrading of the main ventilation fans will ensure a minimum of proper functioning of the ventilation system. The drilling of a further opening will ensure that there is sufficient air in each ventilation area - an increase of 50% in the mine's air volume will be achieved.

Keywords: mine ventilation; ventilation network control; ventilation network optimisation; ventilation efficiency

1. INTRODUCTION

When mining a deposit using the underground method, it is necessary to ensure that air is supplied to each excavation in sufficient quantity and quality. The excavations through which the air flows form a so-called ventilation network. Main ventilation fans are used to ensure the right amount of air. Exploitation of the deposit at ever-increasing levels and further away from the shafts necessitates continuous optimisation of the ventilation network, as well as the need to change the fans [1-5]. One way to optimise the network and increase the efficiency of ventilation may be to make interlevel connections in the form of large-diameter openings. Before such connections are made, the ventilation

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network should be analysed and evaluated by checking the validity of simulation data against actual data, performing simulation calculations for given network states by changing the ventilation method and by assuming the drilling of large-diameter openings and selecting the parameters of the main ventilation fans.

2. MATERIALS AND METHODS

The ventilation network of the mine is an autonomous network, with no connection to the ventilation networks of other mines. It consists of three intake shafts (Shaft No. 2, Shaft No. 3 and Shaft No. 4). Shaft No. 2 supplies 5295 m³/min, Shaft No. 3 supplies 7295 m³/min and Shaft No. 4 supplies only 245 m³/min of air and serves only to refresh the sub-shaft area of Shaft No. 5 (Figure 1).

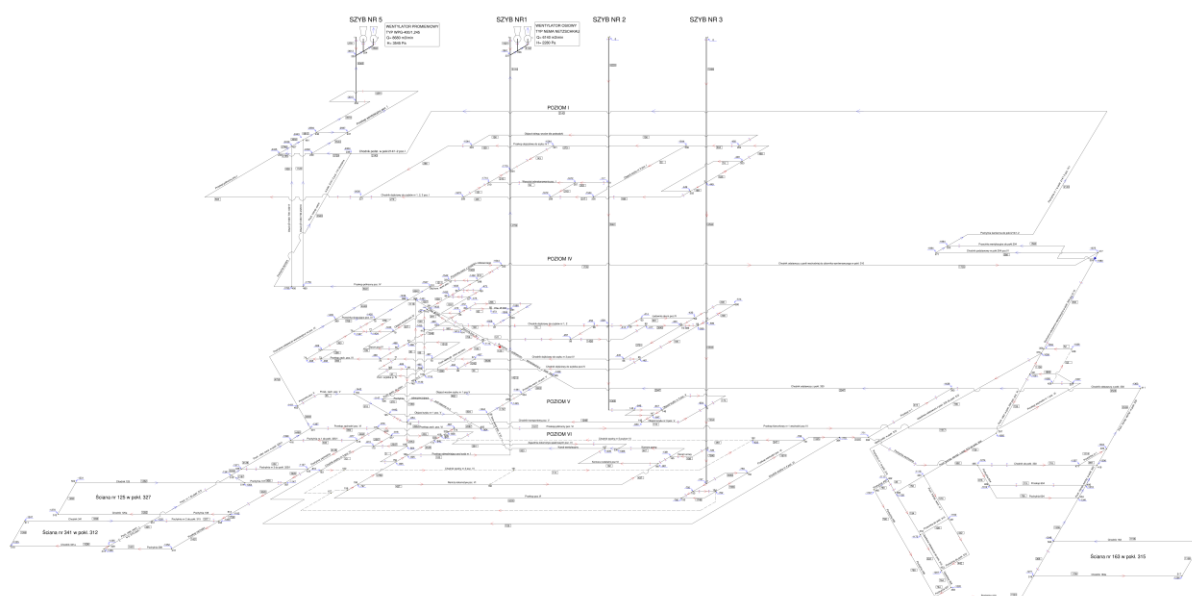


Fig. 1. Mine ventilation scheme [source: own elaboration based on mine data and VENTGRAPH programme]

The ventilation shafts are Shaft No. 1 and Shaft No. 5. In Shaft No. 1, one of the two NEMA NETZSCHKAU fans with an output of 7890 m³/min. and an accumulation pressure of 2350 Pa is in operation. On Shaft No. 5, one of the two WPG-400/1,245 fans with an output of 8235 m³/min. and an accumulation of 3575 Pa is in operation.

The sub-grids associated with the individual ventilation shafts have equivalent openings „A” equal to, respectively, for Shaft No. 1 $A=3.23 \text{ m}^2$, for Shaft No. 5 $A=2.73 \text{ m}^2$. These values allow them to be included in the interval of medium openings, which suggests the ease of ventilating the regions. After analysing the performance parameters (operating characteristics) of the main ventilation fans, it can be concluded that they meet the criteria for economic and stable operation.

In order to update the network model and check its correctness, ventilation measurements were carried out in several sensitive nodes of the ventilation network. The measurements covered mainly two ventilation areas of longwalls 161 and 352 in seam 315, as well as key nodes for the intended changes in the ventilation network.

A total of several dozen nodes were measured, where barometric pressure was measured, temperatures were measured with dry and wet thermometers, and air expenditure was measured in the sidings associated with the nodes. To eliminate atmospheric variations, both barometric pressure and psychrometric temperatures were measured at the surface.

The measurements taken were used to calculate the isentropic potentials at the nodes of the network, based on the method of Henryk Bystroń [6-7]. The calculated values of potentials were compared with the results of ventilation network calculations, using the Ventgraph licensed software - used by the mine [8-10]. The results obtained from the measurements and using the specialised software confirmed the compatibility of the model with the actual measurements.

In order to assess the possibility of increasing the ventilation capacity of the No. 5 shaft sub-network, it was necessary to make changes to the ventilation network model. The changes consisted of:

- in the first stage, the decommissioning of redundant excavations (e.g. excavations after mining and not used in the future),
- establishing a new mining area in seam 327 (Variant „a”),
- making the first simulation calculations,
- assuming the drilling of a first large-diameter opening between Level I (-228m) and Level IV (-461m) with a diameter of 1000 mm after casing it and subsequently performing a second simulation calculation (Variant „b”),
- upgrading the main ventilation fans on Shaft No. 5 and performing the third simulation calculation (Variant „c”),
- upgrading the main ventilation fans at Shaft No. 5 and carrying out simulation calculations along with limiting the air velocity in the Transport and ventilation Slope in seam 214/1-2, Level I-IV to the permissible values and carrying out the fourth simulation calculation (Variant „c1”),
- assuming the drilling of a second large-diameter opening between Level I (-228m) and Level IV (-461m) with a diameter of fi 1000mm after its casing and subsequent execution of the fifth simulation calculation, with simultaneous modernisation of the fans at Shaft No. 5 (Variant „d”),
- assuming the drilling of two large-diameter openings (with a diameter after casing of fi 1000mm), the upgrading of the fans together with the reduction of the air velocity in the Transport and ventilation Slope in seam 214/1-2, Level I-IV, to the permissible values, and the execution of the sixth simulation calculation (Variant „d1”).

The simulation variants are presented by means of a simplified network diagram (Figure 2).

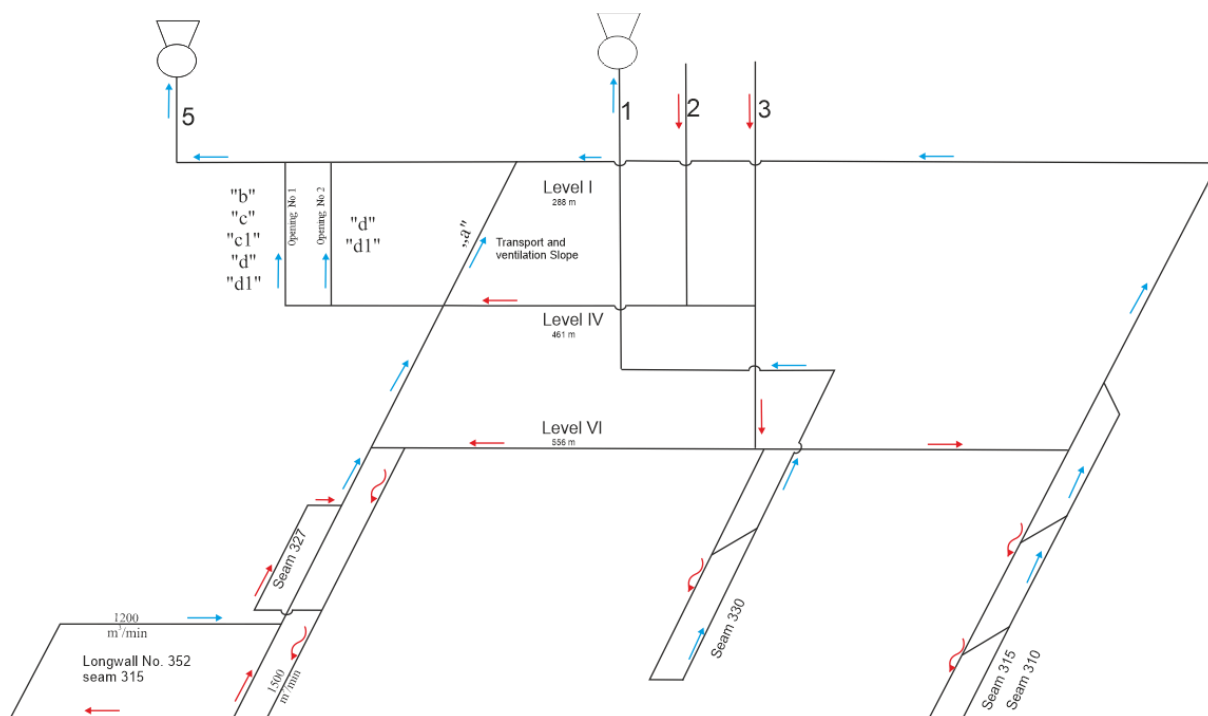


Fig. 2. A simplified diagram with the variants of simulation [source: own elaboration]

3. RESULTS

Variant „a” of the simulation calculations was performed for the following assumptions:

- exploitation of two coal seams - the seams 315 and 327 with the assumption that the minimum amount of air in the area of exploitation of the seam 315 is 1500 m³/min,
- air will be supplied to the longwall through Shaft No. 3 on Level VI, will ventilate the aforementioned areas, and will then be discharged to Level IV and Level I through the Transport and ventilation Slope in seam 214/1-2 on Level I-IV, to the sub-shaft of Shaft No. 5, and to the surface through Shaft No. 5.

After performing simulation calculations of the ventilation network, it can be concluded that:

- 358 m³/min of air will flow in the mining area of seam 327; this will be an insufficient amount of air, even to ventilate the preparatory workings,
- the power of the air current in the longwall in seam 327 will be $N_f=1002W$, and the air current can be described as medium,
- the power of the air current in longwall 352 in seam 315 will be $N_f=2384W$, and the air current may be described as strong.

The evaluation of the power of the current in the longwall (according to the computer simulation of the "Ventgraph" system) was based on the formula [11]:

$$N_f = V_r \cdot \Delta\varphi_r, W, \quad (3.1)$$

where:

N_f – air current power, W,

V_r – longwall air flow rate, m³/s,

$\Delta\varphi_r$ – aerodynamic potential difference in the longwall, Pa

and the following scale:

- $N_f > 6000$ – very strong current,
- $1200 \leq N_f < 6000$ – strong current,
- $240 \leq N_f < 1200$ – medium current,
- $50 \leq N_f < 240$ – weak current,
- $N_f < 50$ – very weak current.

Variant „b” of the simulation calculations was performed for the following assumptions:

- exploitation of two coal seams - seams 315 and 327 with the assumption that the minimum air volume in the area of exploitation of seam 315 is 1500 m³/min,
- the assumption of drilling the first large-diameter opening between Level I (-228m) and Level IV (-461m) with a diameter of ϕ 1000mm after casing it,
- air will be supplied to the longwalls through Shaft No. 3 on Level VI, it will ventilate the aforementioned areas, and then it will be discharged to Level IV and I by means of the Transport and ventilation Slope in seam No. 214/1-2, Level I-IV, and by means of the large-diameter opening, to the shaft bottom of Shaft No. 5 and to the surface through Shaft No. 5.

After performing simulation calculations of the ventilation network, it can be concluded that:

- a large-diameter opening will be drilled between Level I (-228m) and Level IV (-461m) with a diameter ϕ 1000mm after its casing (before casing ϕ 1200mm), with a total aerodynamic resistance of $R=2.50 \text{ kg/m}^7$,
- there will be an air flow of 700 m³/min in the mining area of seam 327; this will be a small amount of air to safely ventilate even the excavations during preparatory works,
- the power of the air current in the longwall in seam 327 will be $N_f=1937W$, and the air current can be described as strong,
- the power of the air current in longwall 352 in seam 315 will be $N_f=2314W$, and the air current may be described as strong.

The aerodynamic resistance of a large-diameter borehole was calculated using empirical formulas for a 100-metre section [12] assuming that the borehole is cased with a diameter of 1000mm. In this case, the formula is of the form:

$$r_{100} = 1.246 \cdot D^{-5.2}, \text{ kg/m}^8, \quad (3.2)$$

where:

D – large opening diameter, m.

Variant „c” of the simulation calculations was performed for the following assumptions:

- exploitation of two coal seams - seams 315 and 327 with the assumption that the minimum air volume in the exploitation area of seam 315 is 1500 m³/min,
- assuming the drilling of the first large-diameter opening between Level I (-228m) and Level IV (-461m) with a diameter of ϕ 1000 mm after casing it,
- establishing the modernisation of the main ventilation fans on Shaft No. 5,
- air will be supplied to the walls through Shaft No. 3 on Level VI, it will ventilate the above-mentioned areas, and then it will be discharged to Level IV and I through the Transport-ventilation Slope in seam No. 214/1-2 on Level I-IV, as well as through the large-diameter opening, to the shaft bottom of Shaft No. 5 and through Shaft No. 5 to the surface by means of modernized ventilators of the main ventilation.

After performing simulation calculations of the ventilation network, it can be concluded that:

- a large diameter opening will be drilled between Levels I (-228m) and IV (-461m) with a diameter of ϕ 1000 mm after its casing (before casing ϕ 1200 mm), with a total aerodynamic resistance of $R=2.50 \text{ kg/m}^7$,
- there will be an air flow of 1449 m^3/min in the exploitation area of seam 327; this will be sufficient to ventilate both the preparatory workings and the entire longwall ventilation area,
- the power of the air current in the longwall in seam 327 will be $N_f=3960\text{W}$, and the air current may be described as strong,
- the power of the air current in longwall 352 in seam 315 will be $N_f=2328\text{W}$, and the air current may be described as strong,
- the Transport-ventilation Slope in seam 214/1-2, Level I-IV air flow will be $4859\text{m}^3/\text{min}$. and this amount will be considerably higher than the permissible air velocity in this excavation ($w>10\text{m/s}$).

Variant „c1” of the simulation calculations was performed for the following assumptions:

- exploitation of two coal seams - seams 315 and 327 with the assumption that the minimum air volume in the area of exploitation of seam 315 is $1500 \text{ m}^3/\text{min}$,
- assuming the drilling of the first large-diameter opening between Level I (-228m) and Level IV (-461m) with a diameter of ϕ 1000 mm after casing it,
- establishing the modernisation of the main ventilation fans on Shaft No. 5,
- air will be supplied to the walls through Shaft No. 3 on Level VI, it will ventilate the mentioned areas, and then it will be discharged to Level IV and Level I through the Transport and ventilation Slope in seam 214/1-2, Level I-IV, and through the large-diameter opening, to the shaft bottom of Shaft No. 5 and to the surface through the modernized main ventilation fans,
- the assumption that air will flow at the maximum permissible speed in the Transport and ventilation Slope in seam 214/1-2, Level I-IV.

After performing simulation calculations of the ventilation network, it can be concluded that:

- a large-diameter opening will be drilled between Level I (-228m) and IV (-461m) with a diameter ϕ 1000 mm after its casing (before casing ϕ 1200 mm), with a total aerodynamic resistance of $R=2.50 \text{ kg/m}^7$,
- there will be an air flow of $1033 \text{ m}^3/\text{min}$ in the exploitation area of seam 327; this will be sufficient to carry out one front of preparatory works, but insufficient to ventilate the entire longwall ventilation area,
- the power of the air current in the longwall in seam 327 will be $N_f=2135\text{W}$, and the air current may be described as strong,
- the power of the air current in longwall 352 in seam 315 will be $N_f=2358\text{W}$, and the air current may be described as strong,
- the transport and ventilation slope in seam 214/1-2, Level I-IV air flow will be $3840\text{m}^3/\text{min}$. and this amount will not exceed the permissible air velocity in this excavation.

Variant „d” Variant 'd' of the simulation calculations was performed for the following assumptions:

- exploitation of two coal seams - seams 315 and 327 with the assumption that the minimum air volume in the area of exploitation of seam 315 is $1500 \text{ m}^3/\text{min}$,
- the assumption of drilling a second large-diameter opening between Level I (-228m) and IV (-461m) also with a diameter ϕ 1000 mm after casing it,
- assuming the modernisation of the main ventilation fans on Shaft No. 5,
- air will be supplied to the walls through Shaft No. 3 on Level VI, it will ventilate the above-mentioned areas, and then it will be discharged to Level IV and I through the Transport and

ventilation Slope in seam No. 214/1-2 on Levels I-IV, as well as through the large-diameter openings, to the sub-shaft of Shaft No. 5 and through Shaft No. 5 to the surface by means of modernized ventilators of the main ventilation.

After performing simulation calculations of the ventilation network, it can be concluded that:

- large diameter openings will be made between Levels I (-228m) and IV (-461m) with a diameter of 1000mm after their casing (before casing of 1200mm), with a total aerodynamic resistance of $R=2.50 \text{ kg/m}^7$,
- there will be an air flow of 1595 m³/min in the exploitation area of seam 327; this will be sufficient to ventilate the entire area,
- the power of the air current in the longwall in seam 327 will be $N_f=4519\text{W}$, and the air current can be described as strong,
- the power of the air current in longwall 352 in seam 315 will be $N_f=2416\text{W}$, and the air current may be described as strong,
- the Transport-ventilation Slope in seam 214/1-2, Level I-IV air flow will be 4327m³/min. and this amount will exceed the permissible air velocity in this excavation ($w>10\text{m/s}$).

Variant „d1” of the simulation calculations was performed for the following assumptions:

- exploitation of two coal seams - seams 315 and 327 with the assumption that the minimum air volume in the area of exploitation of seam 315 is 1500 m³/min,
- the assumption of drilling two large-diameter openings between Level I (-228m) and IV (-461m) also with a diameter of 1000 mm after casing them,
- assuming the modernisation of the main ventilation fans on Shaft No. 5,
- air will be supplied to the walls through Shaft No. 3 on Level VI, it will ventilate the mentioned areas, and then it will be discharged to Level IV and Level I through the Transport and ventilation Slope in seam 214/1-2, Level I-IV, and through the large-diameter openings, to the sub-shaft of Shaft No. 5 and through Shaft No. 5 to the surface by means of modernized ventilators of the main ventilation,
- assuming that air will flow at the maximum permissible speed in the transport and ventilation slope in seam 214/1-2, pos. I-IV.

After performing simulation calculations of the ventilation network, it can be concluded that:

- large diameter openings will be made between Levels I (-228m) and IV (-461m) with a diameter of 1000 mm after their casing (before casing of 1200 mm), with a total aerodynamic resistance of $R=2.50 \text{ kg/m}^7$,
- there will be an air flow of 1554 m³/min in the exploitation area of seam 327; this will be sufficient to ventilate the entire area,
- the power of the air current in the longwall in seam 327 will be $N_f=4170\text{W}$, and the air current can be described as strong,
- the power of the air current in longwall 352 in deck 315 will be $N_f=2336\text{W}$, and the air current may be described as strong,
- the Transport and ventilation Slope in seam 214/1-2, level I-IV air flow will be 3807m³/min. and this amount will not exceed the permissible air velocity in this excavation.

The results of the simulation calculations are shown in the diagram (Figure 3) and in Table 1.

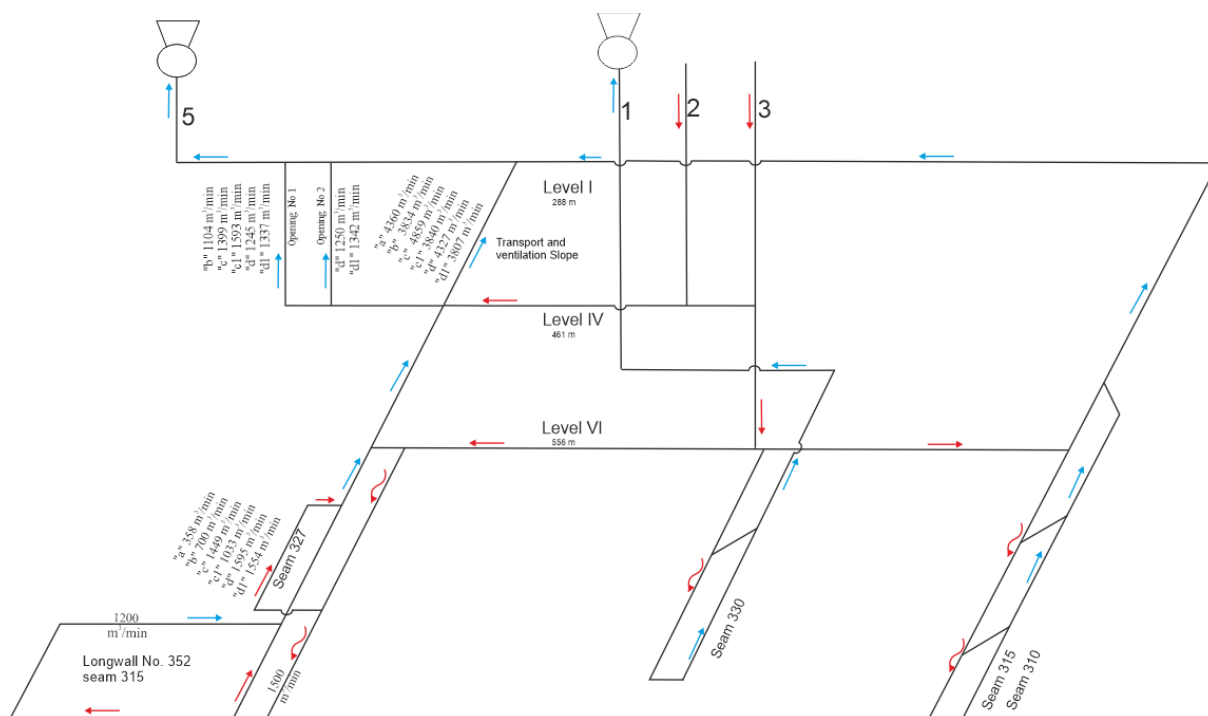


Fig. 3. Results of simulation calculations [source: own elaboration]

Table 1. Simulation and calculation results

Model	Variant	Total fun pressure	Volumetric flow rate	Equivalent hole	Comments
		Δp Pa	V m^3/min	A m^2	
Before retrofitting the fans at Shaft No. 5					
0	current	3575	8235	2.73	Current status
a	I	3410	9215	3.13	Establishment of the second area (seam 327)
b	II	3359	9526	3.26	Execution of the first large-diameter borehole
After upgrading the fans at Shaft No. 5					
c	III	5071	12088	3.37	Execution of the first large-diameter borehole
c1	IV	5140	11627	3.22	As above, and reduction of the air velocity in the Trans.-vent Slope to an acceptable size
d	V	5025	12400	3.47	Execution of the second large-diameter borehole
d1	VI	5051	12224	3.41	As above, and reduction of the air velocity in the Trans.-vent Slope to an acceptable size

Source: own elaboration

4. SUMMARY AND CONCLUSIONS

The work concerned the assessment of the possibility of increasing the ventilation capacity of the No. 5 shaft sub-grid by drilling large diameter openings ϕ 1000 mm, between Levels I (-228m) and IV (-461m), and upgrading the main ventilation fans at No. 5 shaft.

- The simulations carried out were based on the current potential diagram of the ventilation network made with the Ventgraph computer programme, made available by the Mine's ventilation service.
- For the large-diameter openings, it was assumed that they would be drilled between Levels I (-228m) and IV (-461m).
- The diameter of the openings to be drilled should be 1200mm to reach 1000mm after casing, so that the total aerodynamic resistance of each hole will be $R=2.50 \text{ kg/m}^7$.
- Changing the type of casing and the diameter of the openings will change their aerodynamic resistance, so that the results obtained may reflect reality incorrectly and the assumptions made (the correctness of the new ventilation system) will not be achieved.
- In order to ensure a minimum correct functioning of the ventilation system, it should be assumed that at least one large diameter opening will be made and the main ventilation fans at Shaft No. 5 will be upgraded. With such a solution, it should be expected that the permissible velocity in the Transport and ventilation Slope in seam 214/1-2, Level I-IV will be exceeded. Reducing the speed in this Slope to the permissible values will result in a significant reduction of air volume in the ventilation area in seam 327.
- The drilling of the second opening will ensure that there is sufficient air in each ventilation region - an increase of 50% in the mine's air volume will be achieved.
- The operating points of the main ventilation fan at Shaft No. 5 for each of the variants together with the equivalent openings are presented in the form of a table (Table 1) and a diagram (Figure 4).

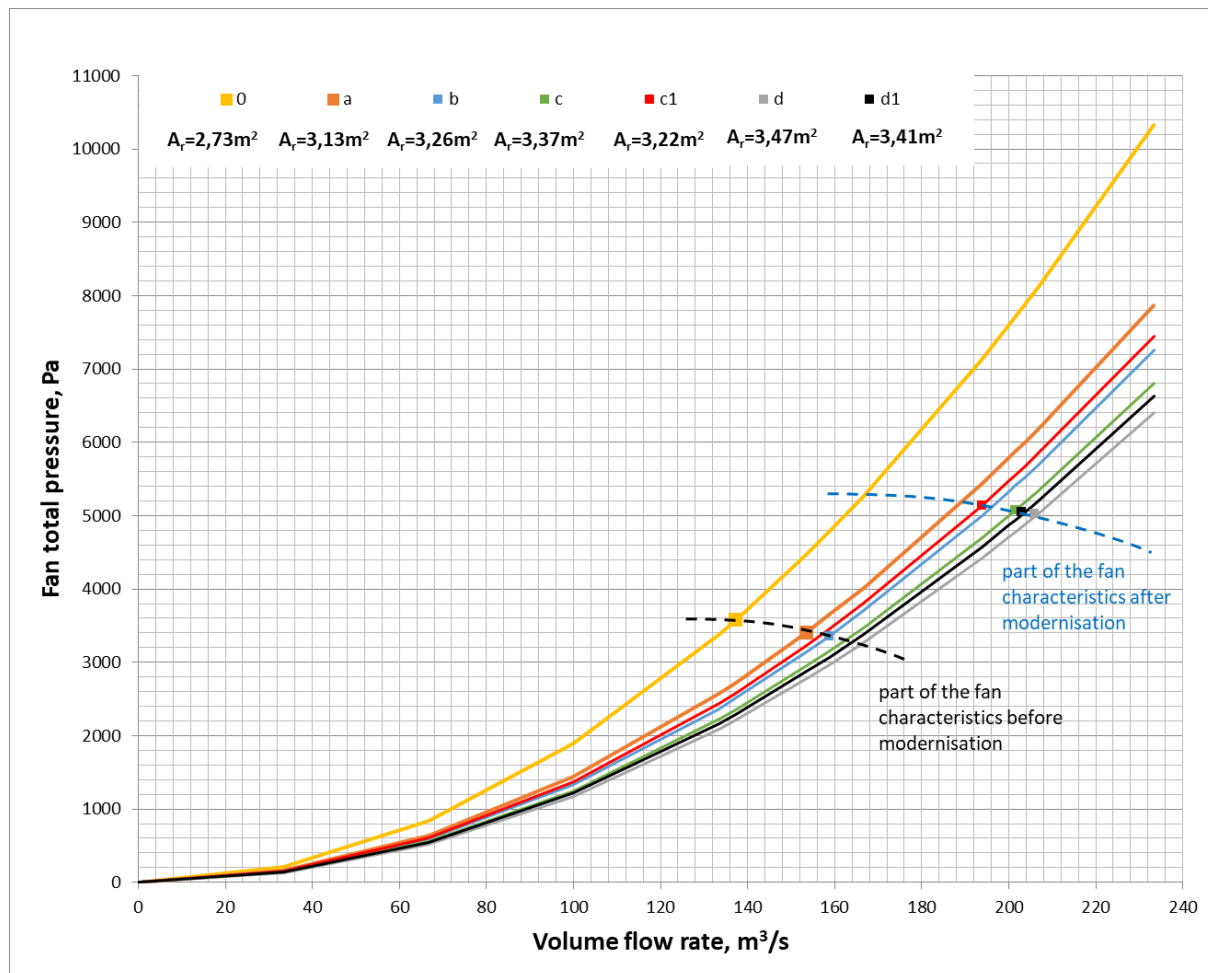


Fig. 4. Fan characteristics before and after modernisation [source: own elaboration]

Due to the high cost and time required for the large-diameter boreholes and fan upgrades, the mine has completed two large-diameter openings as of 30 September 2023. In the second opening, the diameter was increased to 1,200 mm. The current state of the network is shown in Figure 5. The two large-diameter openings allow the mine to operate properly, but without fan upgrades it will not be possible to provide the right amount of air to ventilate further, more distant portions of the deposit.

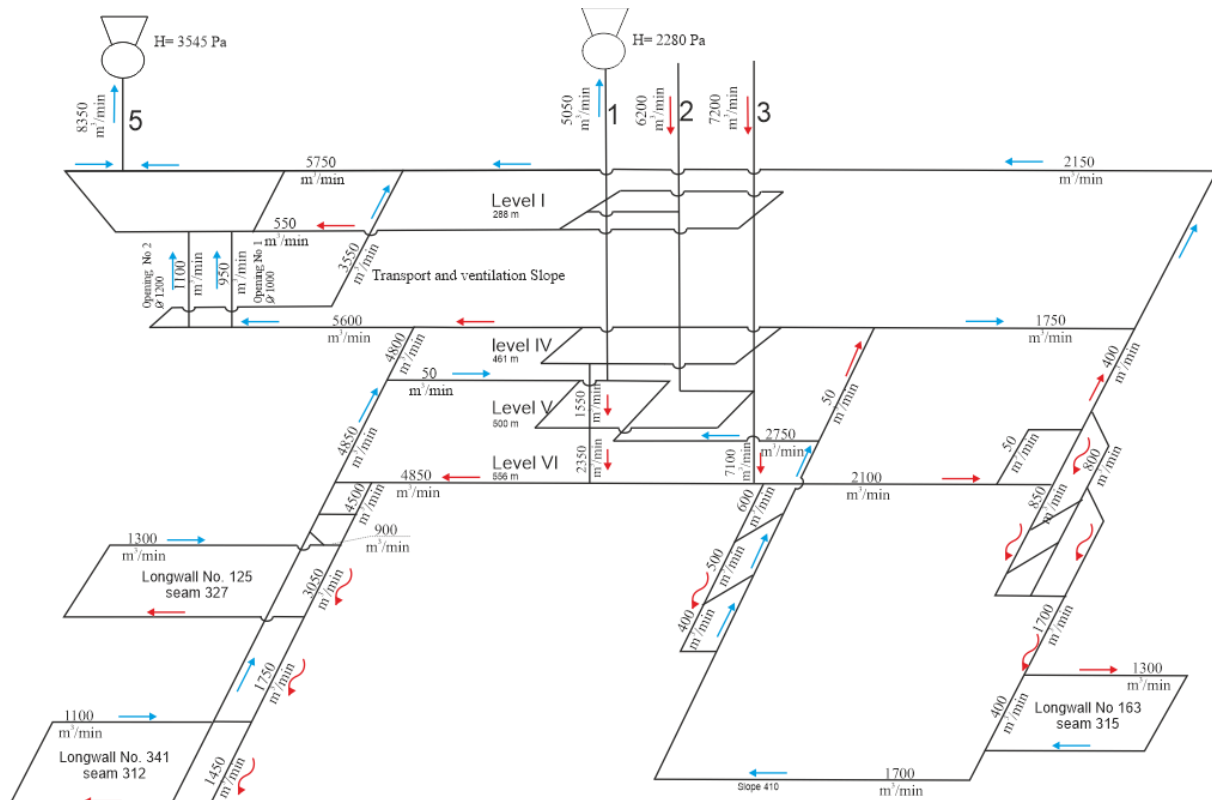


Fig. 5. Ventilation diagram of the mine after two openings - as at 30.09.2023 [source: own elaboration]

ADDITIONAL INFORMATION

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