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Research, Calculation and Proposal of Ventilation Solution for Duong Huy Coal Mine when Mining Down to -250 m Depth

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Abstract. At present, according to the extraction plan in the year 2020 of Duong Huy Coal Company - Vinacomin, the mining is divided into three main zones: Central Zone extracts 06 faces; South Zone extracts 2 faces and Northeast Zone extracts 2 faces. The designated total production of all zones is 1,880,000 tons/year. To ensure the production of each mining zone, exhaust fan stations are installed at ventilation roadway adits with a total of 05 main fan stations. However, in the near future, to ensure and maintain production activities, the mine is being planned and operated using 03 main fan stations. The calculation results for the reasonable working mode of fan stations are as follows: for fan station FBCDZ-8-№32B at level +47 m, airflow is 167.69 m^3/s and air pressure is 243.74 mm H_2O; for fan station 2K56-№30 level +40 m, airflow is 123.37 m^3/s and air pressure is 324.79 mm H_2O; for fan station FBCDZ-8-№32B at level +44 m, airflow is 167.69 m^3/s and air pressure is 354.99 mm H_2O.

Keywords: Main fan, Working mode, Ventilation, Airflow, Air pressure, Air velocity

1. Introduction

In Vietnam, underground mining areas mainly locate in Quang Ninh coal field. Vietnam National Coal - Mineral Industries Holding Corporation Limited (Vinacomin) are currently managing 13 coal companies with 17 mining sites. These sites are operated in small scale with coal production of 0.5-2.5 million tons per year. In general, mine sites are scattered, having complex geological conditions and low technological mechanisation. The ventilation is therefore very complicated. For example, Trang Bach - Trang Khe site of Uong Bi coal mine uses 07 main fan stations, or Quang Hanh coal mine uses 04 fan stations for underground mining ventilation. One critical ventilation problem for Quang Ninh underground coal mines is its difficulty at deeper mining. The roadways become greater and deeper that result in greater air pressure and higher temperature. As the fan stations are located far away from each other, their combination for overall ventilation is more difficult while "air-pulling" often occurs between the fans. During past years, Vinacomin has developed solutions for easy ventilation at deeper mining such as use of modern mining technology, reduction of fan station number and increase of fan power [1, 2]. At Duong Huy coal mine - Vinacomin, the mine operates in three main zones: Central Zone extracts 06 faces; South Zone extracts 02 faces, and Northeast Zone extracts 02 faces. The designated total production of all zones is 1,880,000 tons per year [3]. To ensure the production in each mining zone, exhaust fan stations are installed at ventilation roadway adits with a total of 05 main fan stations: 01 station using fan 2K56-№24, 01 fan station using two parallel fans 2K60-44-№16, 01 exhaust station using fan BD-II-6-№12/2x30, 01 station using fan 2K56-№30 and 01 station using exhaust fan FBCDZ-№12/2x45. In the near future, according to the Vinacomin's approval, Duong Huy coal mine operates at greater depth of -250 m. The mine is designed to reduce fan station from five to three. Therefore, it it necessary to study and calculate the ventilation for mining at -250 m depth with only three main fan stations as designed. It should be noted that because the geo-mining conditions in Vietnam are complex and different from those in the world [4], oversea studies apparently have not focused on the reduction of fan station number in a combined system when mining at greater depth [5, 6, 7, 8].

2. Research and calculation of mine ventilation when mining down to -250 m depth

According to the mine design of Duong Huy coal mine for deeper mining approved by Vinacomin, the total fans are to reduce to only 03 main stations for overall ventilation. A simplified network of ventilation is shown in Figure 1. Based on this network, this paper presents a calculation and determination of main fan stations that are well combined with current underground workings.

2.1 Calculation of mine airflow

From the schedule when mining down to -250 m, the airflow calculated for faces, preparation roadways, stations and leaking airflow are as follows [9, 10, 11]:

Tab. 1. Required airflow for air-consumed excavation at -250 m depth.

Order	Name of air-consumed excavation	Airflow, m^3/s	Note
1	Faces	175.4	
2	Roadway in reparation	119.6	
3	Underground stations	38.8	
4	Air leakage	24.6	

The corresonding total airflow is calculated as:

$$Q_m = 1.1 \times (Q_{lc} + Q_{cb} + Q_{ht} + Q_r) \quad (1)$$

Where: Q_m is total airflow of mine, m^3/s; Q_{lc} is total airflow for all faces, m^3/s; Q_{cb} is total airflow for roadway in preparation, m^3/s; Q_{ht} is total airflow for underground stations, m^3/s; Q_r is total leaking airflow through all excavations, m^3/s.

Thus the total airflow is adjusted and calculated as:

$$Q_m = 1.1 \times (175.4 + 119.6 + 38.8 + 24.6) \approx 394 \text{ m}^3/s \quad (2)$$

2.2 Calculation of mine air pressure

The air pressure of mine is calculated according to PATH diagram network. The air pressure is calculated for each path according to the nodes identified in Fig. 1. Detailed information of the calculation method can be found in Tran, Le [9], Center for mining science [10] and Green Science Development Joint Stock Company [12], Green Science Development Joint Stock Company [13], Green Science Development Joint Stock Company [14]. The calculation result of maximum air pressure path over nodes having equal air pressure is as follows:

At point number 1 having air pressure $h_{max} = h_{min} = 0$ mm H_2O;

At point number 5 having air pressure $h_{max} = h_{min} = 19.68$ mm H_2O;

At point number 7 having air pressure $h_{max} = h_{min} = 22.18$ mm H_2O;

At point number 8 having air pressure $h_{max} = h_{min} = 35.96$ mm H_2O;

At point number 9 having air pressure $h_{max} = h_{min} = 36.88$ mm H_2O;

At point number 11 having air pressure $h_{max} = h_{min} = 43.01$ mm H_2O;

At point number 15 having air pressure $h_{max} = h_{min} = 48.00$ mm H_2O;

At point number 24 having air pressure $h_{max} = h_{min} = 100.64$ mm H_2O;

At point number 28 having air pressure $h_{max} = h_{min} = 134.53$ mm H_2O;

At point number 32 having air pressure $h_{max} = h_{min} = 148.81$ mm H_2O;

At point number 41 having air pressure $h_{max} = h_{min} = 158.21$ mm H_2O;

At point number 44 having air pressure $h_{max} = h_{min} = 166.22$ mm H_2O ;

At point number 46 having air pressure $h_{max} = h_{min} = 168.49$ mm H_2O;

At point number 56 having air pressure $h_{max} = h_{min} = 159.30$ mm H_2O;

At point number 57 having air pressure $h_{max} = h_{min} = 268.09$ mm H_2O;

At point number 60 having air pressure $h_{max} = h_{min} = 289.1$ mm H_2O.

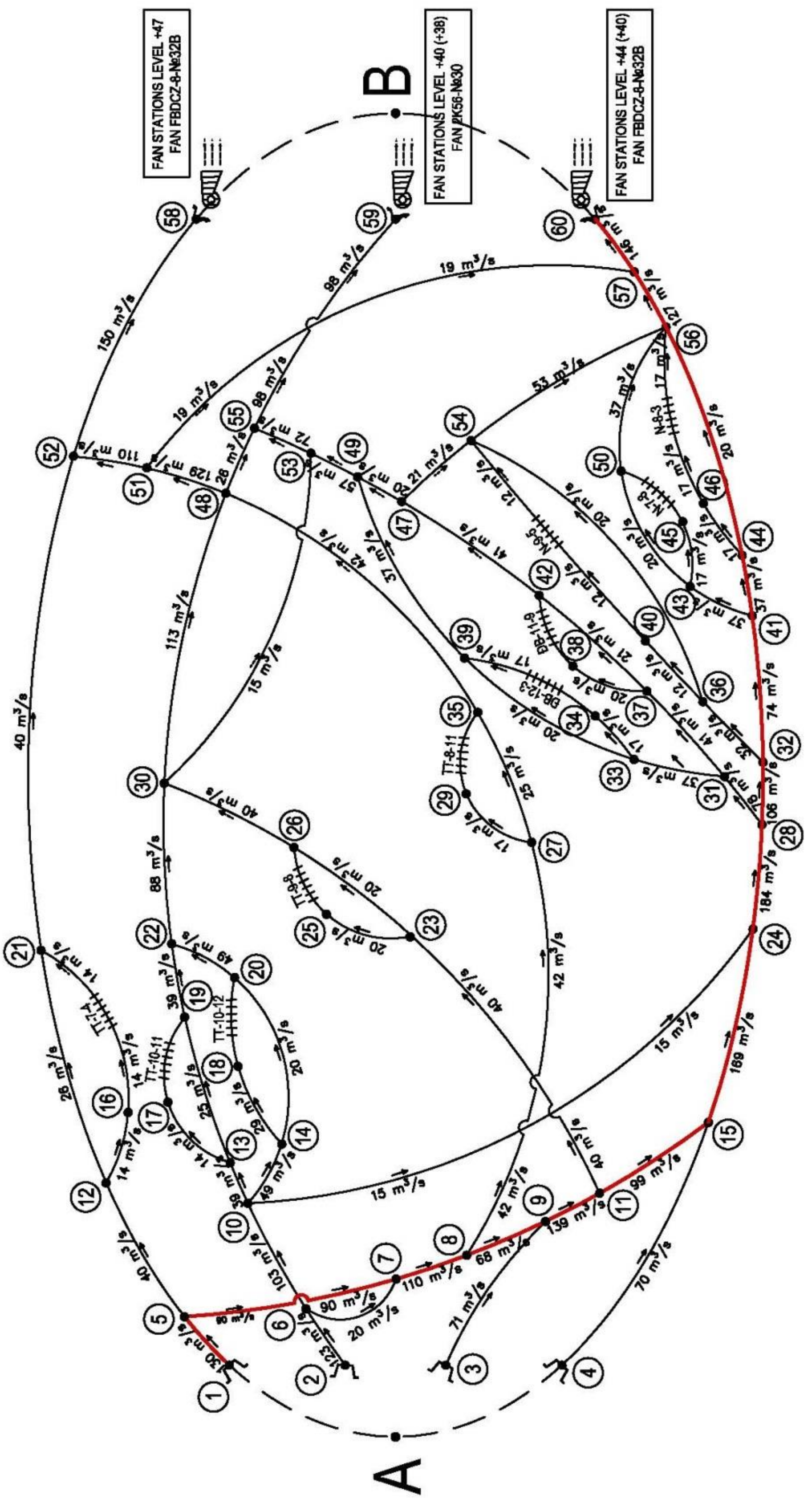

Fig. 1. Simplified ventilation network when 03 fan stations jointly working at -250 m depth.

Hence the maximum air pressure path is determined to go through paths: 1-5-7-8-9-11-15-24-28-32-41-44-46-56-57-60, as highlighted in red color and bold in Figure 1.

The maximum air pressure is: $H_{max} = 289.1$ mm H_2O.

2.3 Calculation of main fan reasonable working mode at -250 m depth

a. Calculation of fan airflow

According to the above calculation, the required airflow for mining at -250 m depth is 394 m^3/s. Based on the determination of air-consumed excavations such as longwall, roadway or station for each fan station, the corresponding distribution for air consumptions and fan stations are as follows:

- Zone served by fan station level +47 m has $Q_1 = 150\ m^3/s \rightarrow Q_{q1} = 1.1 \times 150 = 165\ m^3/s$.

- Zone served by fan station level +40 m has $Q_2 = 98\ m^3/s \rightarrow Q_{q2} = 1.1 \times 98 = 107.8\ m^3/s$.

- Zone served by fan station level +44 m has $Q_3 = 146\ m^3/s \rightarrow Q_{q3} = 1.1 \times 146 = 160.6\ m^3/s$.

b. Calculation of fan air pressure

The fan stations work in combination and parallel in which each fan serves a separate air pressure for a mine site. Therefore, when being operated jointly, each fan air pressure is calculated according to the maximum air pressure from the area that fan serves. The air pressure of fan stations is calculated as follows:

** Air pressure to be created by fan station level +47 m*

Based on the calculation result, a required air pressure H_{m1} of 199.1 mm H_2O [10, 15, 16] is used to calculate mine resistance.

The resultant resistance is: $R_{m1} = 199.1/150^2 = 0.0088$ kμ.

The resistance created by fan is:

$$R_{tb1} = 0.05 \times 3.14/3.2^4 = 0.0015 \text{ kμ}.$$

The air pressure served by fan station level +47 m is calculated as:

$$H_{q1} = (0.0088 + 0.0015) \times 165^2 = 280.42 \text{ mm } H_2O.$$

** Air pressure to be created by fan station level +40 m*

Based on the calculation result, a required air pressure H_{m2} of 232.6 mm H_2O is used to calculate mine resistance:

The mine resistance is: $R_{m2} = 232.2/98^2 = 0.024$ kμ

The resistance created by fan is:

$$R_{tb2} = 0.05 \times 3.14/3^4 = 0.0019 \text{ kμ}.$$

The air pressure served by fan station level +40 is as follows:

$$H_{q2} = (0.024 + 0.0019) \times 107.8^2 = 280.42 \text{ mm } H_2O.$$

The air pressure needs to be created by fan is:

$$H_{q2} = (0.0139 + 0.0019) \times 154^2 = 300.98 \text{ mm } H_2O.$$

** Air pressure to be created by fan station level +44 m*

Based on the calculation result, the required air pressure H_{m3} of 289.1 mm H_2O is used to determine mine resistance

The mine resistance is: $R_{m3} = 289.1/146^2 = 0.0139$ kμ.

The resistance create by fan is:

$$R_{tb3} = 0.05 \times 3.14/3.2^4 = 0.0015 \text{ kμ}$$

The air pressure served by fan station level +40 m is:

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$$H_{q3} = (0.0139 + 0.0015) \times 160.6^2 = 397.22 \text{ mm } H_2O.$$

From the airflow and air pressure calculated for the above 03 fan stations, the fans are consequently chosen as follows:

- Fan station №1 level +47 m is fan FBCDZ-8-$N_0$32B with impeller blade angle of 43/35^0 or equivalent.

- Fan station №2 level +40 m is fan 2K56-$N_0$30 with impeller blade angle of 40^0.

- Fan station №3 level +44 m is fan FBCDZ-8-$N_0$32B with impeller blade angle of 40/32^0 or equivalent.

3. Verification of working mode of fan stations when mining at -250 m depth

The airflow is distributed for air-consumed excavations as in Figure 1. In order to verify the working mode of 03 main fan station when jointly working in -250 m depth, this paper uses Kazamaru program for distribution of airflow. The results are shown in Figures 2, 3, 4, 5.

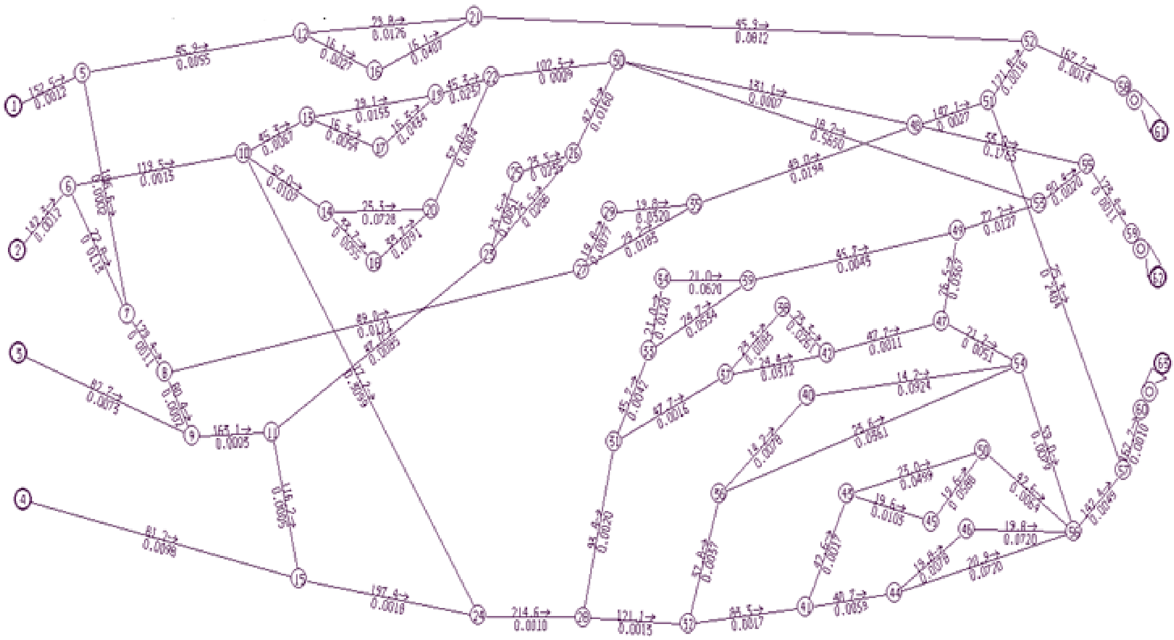

Fig. 2. Verification of working mode when 03 fan stations jointly working at -250 m mining depth.

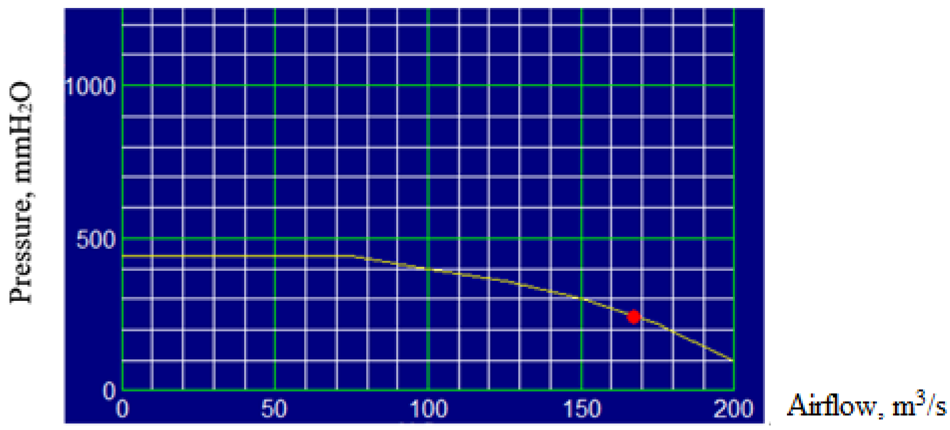

Fig. 3. Working point of Fan FBCDZ-8-№32B level +47 m.

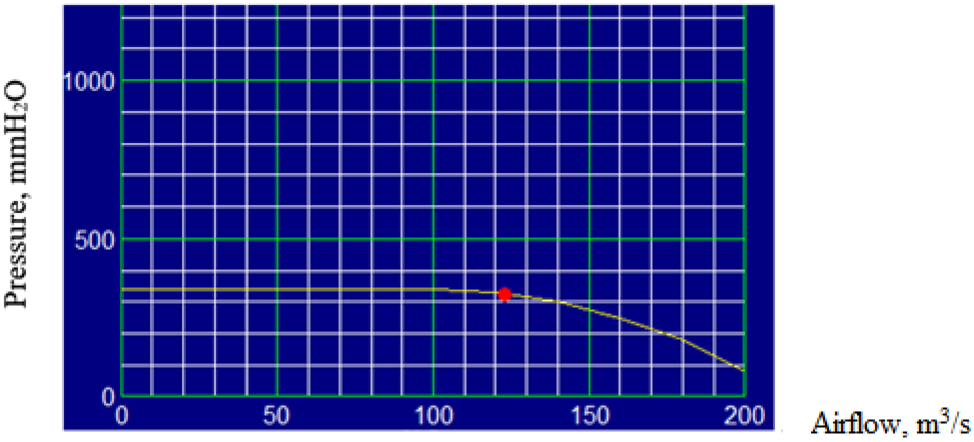

Fig. 4. Working point of Fan 2K56-№30 level +40 m.

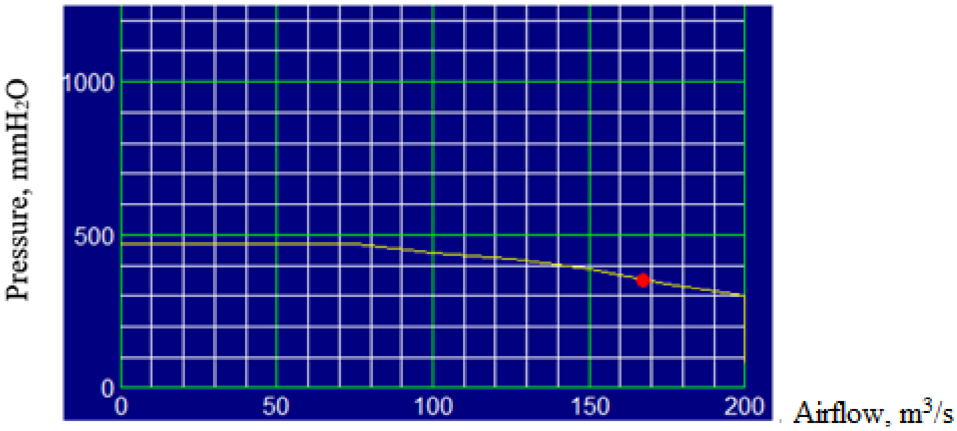

Fig. 5. Working point of Fan FBCDZ-8-№32B level +44 m.

The verification shows that the air pressure in ventilation paths satisfies the requirement. This indicates that the capacity of the above 3 fan stations completely fulfills the requirement when mining at depth of -250 m. The corresponding working mode of fans is as follows:

Tab. 2. Calculation of airflow, air pressure when 03 fan stations in use.

Order	Fan stations	Airflow Q_{yc}, m^3/s	Air pressure, H, mm H_2O
1	Fan station №1 level +47 m uses fan FBCDZ-8-№32B	167.69	243.74
2	Fan station №2 level +40 m uses fan 2K56-№30	123.37	324.79
3	Fan station №3 level +44 m uses fan FBCDZ-8-№32B	167.69	354.99

4. Proposal of solution to complete ventilation system at -250 m depth

To maintain the ventilation for the mining schedule at -250 m depth using current underground excavations, the following technical issues must be solved in the near future:

- The designated 3 fan stations ensure the ventilation of the mine down to -250 m. However, ventilation path 15-24 (railway-setting roadway -250 m Zone TT.II) has an air velocity of 8.45 and path 24-28 (in-rock roadway -250 m Zone DB.I) has a velocity of 9.2 m/s. The velocities exceed the maximum value of 8 m/s according to QCVN 01/2011-BCT [17]. Therefore, the roadways must be enlarged to reduce the velocity.

- Path 56-57 (in-seam roadway -100 m V8 and crosscut -100 m N.II) has the highest air pressure of 78.8 mmH_2O; its cross-sectional area should be enlarged for pressure reduction.

- To ensure the air velocity of paths 15-24 and 24-28 and to reduce the air pressure for roadways in path 56-57, it is suggested to enlarge roadway's cross-sectional area or to properly drive roadway from which the airflow through fan station +44 m reduces by 10 m^3/s.

- An air window is additionally installed at -250 m to adjust airflow for each air-consumed excavation.

- According to the mine design for -250 m depth, the mine is ranked as Class III according to Ministry of Industry and Trade (2020) However, during the extraction, mining technology may change which accordingly changes the coal production. This results in a change in the methane gas emission of mine as well. Therefore, it is necessary to re-calculate the methane-class of mine for appropriate ventilation.

5. Conclusions

When mining down to -250 m, the reduction in main fan from 05 to 03 fan stations is to facilitate the mine management and to ensure a proper ventilation mode for mine. The calculation results have determined proper working mode of each fan station at +47 m, +40 m and +44 m as follows:

- Fan station FBCDZ-8-№32B level +47 m works with an airflow of 167.69 m^3/s and air pressure of 243.74 mm H_2O;

- Fan station 2K56-№30 level +40 m works with an airflow of 123.37 m^3/s and air pressure of 324.79 mm H_2O;

- Fan station FBCDZ-8-№32B level +44 m works with an airflow of 167.69 m^3/s and air pressure of 354.99 mm H_2O.

To ensure the mine safety when operating the three main fan station without changing the current underground excavations, the cross-sectional area of the following roadways should be enlarged for legally air velocity and pressure: railway-setting roadway level -250 m Zone TT.II, curved roadway level -250 m, in-rock roadway -250 m Zone DB.I; roadway -100 m V8 and crosscut -100 m N.II.

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