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OPTIMIZATION OF VENTILATION WITH COMPLEX VENTILATION NETWORKS OF MINES

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ABSTRACT

In the article, taking into account the tendency to increase the production capacity of underground mines and the complexity of mining conditions in the mining of deep horizons, the operational costs of mining and transporting ore, as well as the volume of air required for ventilation of mine solders, the amount of air in the ventilation network is also increasing proportionally. the ways of air distribution and reduction of air losses are presented.

Keywords: mining, ventilation, mining, air flow, depression, air speed, horizon, thermohygrometer, anemometer, laser rangefinder, air-depression survey.

The tendency of increasing production capacity of underground mines and deepening of mined horizons, in connection with this complication of mining conditions and reduction of content of the useful component in ore leads to the necessity of intensive involvement of new reserves in development. At the same time, the operating costs of excavating and transporting ore are increasing, and the volume of air required for ventilation is also increasing proportionally.

In world practice, during the development of ore deposits, the possibility of increasing production capacity is solved by increasing the number of working horizons and sections, the fleet of mining and self-propelled equipment, the productivity of which is provided by the use of equipment with increased geometric dimensions and power drives. All this leads to the need to reconstruct the underground mine in terms of increasing the number of mine workings or expanding their cross-section.

The analysis of the experience of mining enterprises, developing the deposits by underground method, has shown that the distance from the suction point to the face is not less than 1/3, and sometimes up to half of the whole way of air movement.

Therefore, the development and justification of technological solutions to optimize the ventilation process and reduce aerodynamic resistance and depression of the ventilation network when increasing the production capacity of the mine is an urgent scientific and practical task.

For example, the underground mining section of the Karakutan mine is currently mining the NTS-2K and NTS-1K sections. The following are the results of the NTS-2K studies.

Plot NTS-2K mines ore bodies No. 51 and 7 with the area of ore body No. 51 0.2 km2, ore body No. 7 - 0.15 km2. Opening of reserves at 480 m and below is carried out by a sloping transportation ramp NTS-2K and a central ventilating rising (CVV). NTS-2K is used to deliver rock mass to the surface by mine dump trucks, deliver materials and equipment, lower and lift people and partially deliver air.

Supply of fresh air to the mine workings and laying of utilities is carried out by the central ventilation uprising. The mine has adopted a field pattern of site preparation for development. At the same time, appoach slabs and field haulage drifts are passed at each horizon from the STS. The field drifts are used to pass orts that divide the mine field into extraction areas. The mining method is a drilling and blasting method. Nobelit-216Z is used as an explosive.

Earlier studies have established that the ores are essentially quartz, low-sulfide and belong to the category of silicosis hazardous. Intervening rocks and ores are silicose hazardous, have no tendency to caking and spontaneous ignition and are characterized by medium stability. The decline angle is from 400 to 550. The hardness coefficient of the rocks on the Protodiakonov's scale is 12-17, the ores are 16-19. The volumetric weight of the ore is 2.66 t/m3, the host rocks - 2.5 g/t. The ores are essentially quartz, low-sulfide with free silica content of 60-78.8 %.

Proceeding from the mining-geological and mining-technical conditions (stable ores, steep dip angle), mining of ore bodies is carried out by a system of development with ore junking and small bore holes for ore extraction from the sub-storey drifts. Scheme of preparation of ore bodies for clearing excavation.

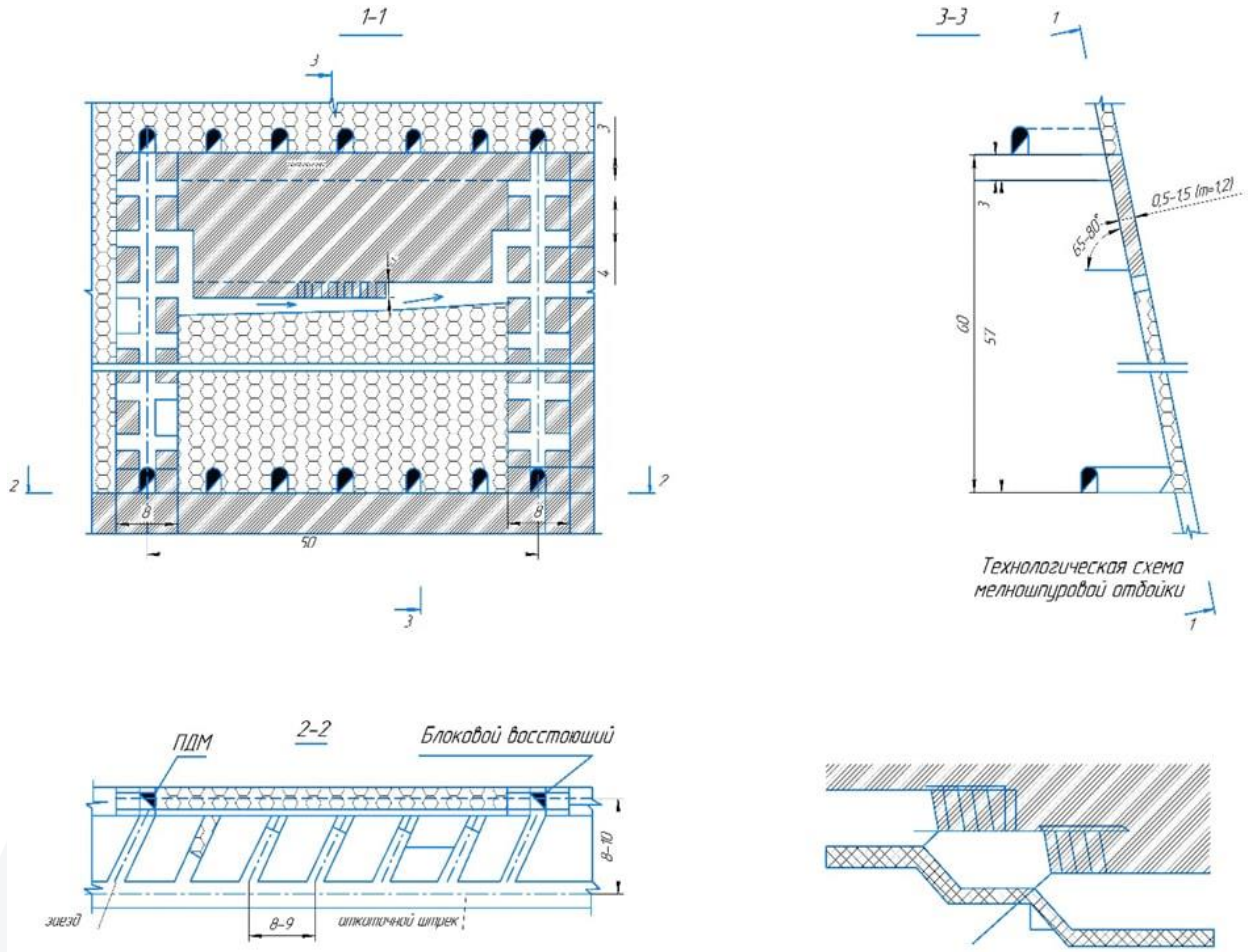

Fig.1. Scheme of the purification unit with ore storing

According to the mine at the time of the research by air-depression survey mining and preparatory work was carried out at +360m; +300m and +240m horizons in the following blocks:

-horizon +300-360m, workable blocks- 92 - 93b; block - 93b-94;

-horizon +240-300m, workable groups: -block 101-102; block 102-103; block 103; block 103-104.

Preparation and cutting works were carried out at the horizons:

horizon +420m; horizon +360m; horizon +300m; horizon +240m and the floors below.

Delivery of the rock mass from the mining blocks and drifting faces to the unloading point (ore-stacking) is performed by ST-2G and ST-7 loading-delivery machines. Further, the rock mass is by-passed by conveyor to loading point, and then the rock mass is transported by underground dump trucks MT 2010 or PAUS 8000 to the surface by NTS-2K. Dump trucks are loaded from under the ore pass with the help of vibroplatform VDPU.

At the time of the airborne survey, loading and delivery operations were performed:

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- at the NTS-2K site with MT 2010 dump trucks - 1 unit, PAUS 8000 - 3 units, ST-2G loading and delivery trucks - 2 units, ST-7 - 2 units;

In underground mines auxiliary equipment is used:

- PAUS MINCA underground bus - 1 unit;
- Explosive material delivery vehicle PAUS-1 unit.

Theoretical basis of the mine ventilation scheme and fan operation

The mode of operation of one fan per network, which is determined by its capacity and depression (Q, H), can be determined by analytical and graphical method.

The essence of the analytical method is to replace the graphical characteristic of the fan with a suitable mathematical expression H(Q), the graph of which would be close to the characteristic of the fan, at least in the area of its industrial use. The most widespread is the equation of the following form

$$H = a - bQ^2 \qquad (1)$$

where "**a**" and "**b**"-numerical parameters determined by the graphical characteristic of the fan.

For this purpose, two points are selected on the working branch of the characteristic (preferably at the ends of the selected section of the characteristic). Parameters of the aPageroximate fan characteristic are determined under the conditions of its passing through both selected points, for which the coordinates of these points taken from the graph are written down: Q1, H1, Q2, H2. Then two equations are made

$$H_1 = a - bQ_1^2 \qquad (2)$$

$$H_2 = a - bQ_2^2 \qquad (3)$$

These equations are linear with respect to the unknowns "a" and "b". Since the coefficients at the unknown "a" in both equations are the same, the easiest way to solve the system of equations (2), (3) is to subtract the second equation from the first. This eliminates the unknown "a" and results in the simplest equation relative to "b"

$$b = \frac{H_1 - H_2}{Q_2^2 - Q_1^2} \qquad (4)$$

By substituting the found value "b" into any of the equations (2), (3) we can determine the parameter "a".

Dependence of depression on airflow for any ventilation network, is expressed by the equation, which is the equation of the characteristic of the ventilation network:

$$H = RQ^2 \qquad (5)$$

where R-aerodynamic resistance of the ventilation network.

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By equating the right sides of equations (1), (5), we find the calculated fan capacity or air flow rate in the network:

$$Q = \sqrt{\frac{a}{b+R}} \tag{6}$$

Substituting this expression into equation (5), we determine the calculated value of depression

$$H = \frac{a*R}{b+R} \tag{7}$$

The graphical method of determining the fan operation mode consists in the graphical construction of the fan characteristic, which is taken from reference sources, and the network characteristic, which is built according to equation (5), on a single drawing at the same scale. Coordinates of the point of intersection of the fan characteristic and the ventilation net characteristic determine Q and H values. It is evident that when one fan works for a ventilation net, its productivity and pressure must satisfy both its own characteristic and the net characteristic, i.e. be graphically determined by the point of intersection of the fan and net characteristic.

Therefore, any fan can operate in a steady state with an efficiency factor not less than 0,6, the resistance of which is within $R_{min} \leq R \leq R_{max}$. When the fan is operating on any network with a resistance R, its capacity can only vary within a certain range from Q_{min} to Q_{max}.

Research Results

Optimization of ventilation by reducing the critical path of air movement and the implementation of local isolated ventilation areas of the mine, where directly conducted mining operations, made by the example of the mine "Karakutan". Initial data and calculation information were taken from the materials of the report "Conducting air-depression survey at underground facilities of Karakutan mine RU GMZ-1" conducted by the central design bureau of Navoi Mining and Metallurgical Plant JSC with the participation of the author of the article.

At Karakutan mine during the air-depression survey were used instruments, thermometer DT-8892 (1 unit), anemometer APR-2m (1 unit), laser rangefinder GLM 250 VF (2 units).

During the air-depression survey was carried out to measure the amount of air passing through the main mine workings of the horizons, the distribution of air in the ventilation networks of the mine, the measurement of barometric pressure at the junction of mine workings and in places where ventilation doors were installed. At the measurement points the cross-section of the mine workings was measured, the

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direction of the air jet was recorded. During the examination of the main fan units the main parameters of the fans were determined (speed and amount of air suPagelied, pressure and electrical parameters of the fans).

Ventilation of NTS-2K section is performed by blowing method by flank scheme. Fresh air is suPagelied to the working horizons in the cleaning and preparatory work areas by the main ventilation unit VOD-21M, installed at the mouth of the central ventilation ascending (CVV). The exhaust air is discharged into the atmosphere through the NTS-2K and adits 53 and 54.

Ventilation of preparatory and cut mine workings at NTS-2K sections is carried out by fans of local ventilation VME-5 and VME-6. Blocks are ventilated at the expense of general mine depression.

Table 1.
Parameters and instruments for measuring air-depression survey

No	Parameters	Unit of measure	Instruments
1	v – air velocity	m/s	Anemometer
2	S – trench area	m^2	tape measure
3	k – clogging coefficient of the section	unit	tape measure
4	N – number of anemometer revolutions	unit	anemometer
5	T – measuring period	seconds	stopwatch
6	Q – air flow rate, $Q = kSv$	m^3/s	
7	P_{CK} – velocity head	daPa	depressiometer, air tubes
8	γ – average specific gravity of air	N/m^3	
9	g – acceleration of gravity	m/s^2	
10	$v_{cp} = \sqrt{\frac{(P_{CK1} + P_{CK2})}{\gamma \cdot 1{,}2} \cdot 2g}$		

The air velocity is the length of the path L of its particles in time T under the action of a natural source of energy, such as natural draught or a fan, i.e.

$$v = \frac{L_2 - L_1}{T_2 - T} \qquad (8)$$

where L_1, L_2 are the length of air movement path, m, respectively; T_1,T_2- time, s.

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According to the expression (1), air speed on the mine workings section between the points L_1, L_2 and in time is averaged, or air speed in one point of the mine workings section and in time is averaged.

In the mines, where the air on the way of its movement is lost in the form of leakages through the ventilation facilities, the air speed is averaged by measurements along the mine workings and in time.

The principle of air velocity measurement with anemometer is to transfer the velocity pressure to the blades or cups of the impeller, which is driven in rotation.

The speed of rotation of the impeller is directly proportional to the air velocity:

$$v = a + b\frac{N_2 - N_1}{T_2 - T_1} \qquad (9)$$

where a , b - coefficients peculiar to a given anemometer (Fig. 1); N_2 , N_1 - number of divisions of the anemometer's turntable, units; T_1,T_2 - time of measurement, s.

If there are air leaks along the excavation, the air speed is measured along its length in at least two measuring points (Fig. 2) and then averaged along the excavation length.

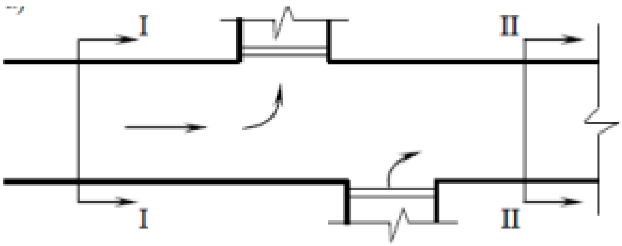

Fig. 2. Scheme of measuring the average air speed in the mine working with air leaks: I-I, II-II- points of measurement

Using the measured air velocity, determine the airflow according to the formula

$$Q = v \cdot S \qquad (10)$$

where S - mine cross-section, m² ; v - air velocity, m/s.

Another common way to measure the air velocity is to use air-measuring tubes.

When measuring the air velocity in one point of the mine working, the average velocity is determined (Fig. 2) by the following formula

$$v_{cp1} = \sqrt{\frac{P_{CK} \cdot 2g}{\gamma}}, \qquad (11)$$

P_{sk} - velocity pressure of air, Pa;

g - acceleration of gravity, m/s²;

γ - specific weight of air, γ = 1.2-9.81 N/m³.

Average air velocity between two measuring points is determined (Fig. 2) by the formula

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$$v_{cp1,2} = \sqrt{\frac{(P_{CK1} + P_{CK2}) \cdot 2g}{\gamma \cdot 1{,}2}}, \qquad (12)$$

where: P_{sk1}, P_{sk2}- respectively, air pressure velocities in the first and second points of measurement, Pa; $\gamma_{1,2}$ - average specific weight of air, N/m^3.

According to the measured air velocity, the air flow rate is also determined by the formula (10).

The obtained value of air velocity according to formula (9) corresponds to the average velocity in one point of the excavation (Fig. 2).

Discussion

In the course of research on the air-depression survey at the site of NTS-2K found that the site is a very complex diagonal ventilation network with separation of air flow by horizon. Ventilation network of the central ventilation uprising NTS-2K on the conditions of the characteristic is divided into 2 routes. The first route VDS begins outside the portal NTS-2K and ends with a field drift number 1 aPageroach (to the CVV horizon +420m) consists of 50 points in which measured such parameters as the cross section of workings (m2), the jet stream speed (m/s), the amount of air (m3/min), relative humidity (%), pressure (Pa), temperature (K), air density (kg/m3) and depression (daPa).

The second route begins with a slope number 3 and the mouth of the horizon +360m and ends with the beginning of the horizon +240m, also consists of 50 points of VDS measurements. Measurements of parameters and indicators are identical on a route №1. Vode research established the calculation of the amount of air determined excavation block, mining works during sinking cut and preparatory mine workings of technological chambers, the slope of the NTS-2K and other auxiliary mine workings. It was established that the main factor for calculating the air requirements of the working horizons is the liquefaction of diesel equipment gases to sanitary norms. The total amount of air suPagelied to the underground mine workings at the NTS-2K section must be at least 80.8 m^3/s.

Table 2 summarizes the air requirements of the horizons and areas of mining-capital, mining preparation and cleaning operations at the NTS-2K site in its current position.

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Table 2 Air requirements of NTS-2K sections of the Karakutan mine

№	Name of fresh air consumers	Air demand of the site, m³/s
1	2	3
	NTS-2K sites	
	Horizon 420 m	
1.	Preparation and cutting work: - Driving horizontal workings, 1 face, 1x1.65 m³/sec; Total for preparatory and cutting works with account for $k_{z.p}$=1,43	1,65 2,40
	Horizon 360 m	
2.	Preparatory and cutting work: - sinking of vertical workings, 1 face, 1x0.7 m³/s; - Driving of horizontal workings, 1 face, 1x1.65 m³/sec; Total for preparatory and riPageing operations taking into account the coefficient $k_{z.p}$=1,43	0,7 1,65 3,4
	Horizon 300 m	
3.	Mining preparatory works: - Field drift at the mountain. +320m NTS-2K, 1 face, 1x 1.65 m³/s;	1,65
	Total for preparatory and rifling works, taking into account the coefficient $k_{z.ya}$ - 1.4E	2,4
4.	Cleaning works: Ore mining by the system with ore storing: - two blocks, 2*3.3 m³/s; Total for clearing works	6,6 6,6
5.	Total for the horizon of 300 m, taking into account the coefficient of uneven air distribution k_{zap} = 1.1	9,9
	Horizon 240 m	
6.	Cleaning works: Ore mining by the system with ore storing: - two blocks, 1 *2.0 m³/s; Total for clearing works	2,0- 2,6
7.	Total for the NTS-2K site on the factor of cleaning and preparatory work, taking into account leaks kt = 1.1	19,5
8.	Total for the site NTS-2K on the factor of liquefaction of diesel equipment gases, taking into account the simultaneous operation of PDM and dump trucks, Q =(620 + 520 hp)x5<0.85/60 = 80.8	80,8
9.	Adopted to calculate the air consumption of the NTS-2K section	80,8
10.	Fan capacity of VOD-21M including external leakage (10 %)	88,9

Comparative results of the measured (actual) and calculated values of the required amount of air and the availability of the site NTC-2K are shown in Table 3.

Table 3. Fresh air suPagely of the mine and mining sites

Air Consumers	Quantity of air, m3/s		Provision, %
	measured	calculated	
NTS-2K sites			
For ventilation of cleaning and preparatory work	14,3	19,5	73,3
To ventilate horizons and NTS-2K from diesel exhaust	62,8	80,8	77,7

Conclusion

The productivity growth of an underground mine is limited by the amount of ventilation air suPagelied and discharged from the underground workings. That is, if the volume of air for ventilation increases, the horizontal section of the mine workings must be enlarged in order to meet the standard speed of air movement in them. This requires reconstruction of the capital mine workings, which ensure the passage of the entire volume of air.

Provision of NTS-2K area with fresh air, calculated on the basis of the actual amount of air suPagelied to the mine, to the horizons, compared with their air requirements was 77.7%. Value of demand of NTS-2K section in fresh air was 80.8 m3/s. The dominant factor in calculating the air demand at both sites is the need to liquefy gases of diesel equipment to sanitary standards.

Productivity of the fan VOD-21M, installed on the central air intake of the NTS-2K site during VDS was 68.4 m3 / s, 62.8 m3 / s of which is fed into the mine. Static pressure developed by the fan was 92.5 daPa. Mine depression at the time of the air-depression survey was - 87.3 daPa. These parameters of VUGP operation are reached at fan impeller rotation frequency of 750 min-1, which blades are set at 25°. To provide air consumption of 80.8 m3 /s at the section of NTS-2K it is recommended to increase air suPagely by transferring the setting angle of impeller blades of fan VOD-21M to 35°.

Actual solution of the above tasks is the development and aPagelication of technical solutions to control the air flow of the ventilation network using methods of aPageroaching the sources of artificial draught to the areas of mining operations, air valves type "briar valve" made of waste conveyor belts, air curtains and portable and on self-propelled machines air ejectors, as well as other methods of changing the aerodynamic resistance of mine workings.

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