Testing a new type of mine brattice and its applications in production units

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Abstract. The article describes the ventilation schemes of the potash mine production units, in which, due to the action of natural draughts (thermal depressions), as well as the use of portable mine brattice (MB), safety and energy efficiency of mining operations is increased. The design and test results of a new type of mine brattice capable of quickly and reliably isolating a mine site from the passage of "excess" air (normal ventilation mode) and flue gases (emergency ventilation mode) are given.

1 Introduction

To increase the profitability of production, underground mining enterprises are actively increasing the volume of mineral extraction every year. As a result of this, the number of mine openings and production units that need to be constantly supplied with fresh air is increasing. The distance from intake shafts to mining sites is also increasing, which results in the need to increase the volume of air supplied to the mine (shaft). As a result, the specific economic costs of ventilation increase, the process of air distribution between the mine openings becomes more complicated, and the problem of predicting the routes of flue gas and/or air masses in case of emergencies (e.g., in case of a fire in the mine openings) arises. In this case, it becomes more and more difficult to ensure safe working conditions without compromising production at an underground mining enterprise, so a new approach is required to solve the problem of air supply to working areas in energy-saving mode while maintaining the requirements for mining safety.

There are two methods to regulate the air distribution between mine openings: positive when fans are used to direct air into areas that need to be ventilated, and negative when areas that are not intended to be ventilated are isolated with mine brattices.

The first method requires additional energy costs, so a negative regulation method using a mine brattice was considered for energy-efficient ventilation.

One more factor for which mine brattices were chosen as the object of development is the fact that these devices protect the working zone where miners work from poisoning by flue gases in case of a fire, and localization of the area of fire from air intake into it.

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2 Results

It is possible to reliably isolate the mining opening from the penetration of air or flue gases through the air brattices [1-3]. The brattice filled with air takes the form of the opening and smoothes out any irregularities in its surface. However, in the case of large mine openings, a large volume of air is needed to construct an air brattice. In this case, the installation of the brattice will require significant time expenditure, as well as a power supply source for the high-pressure compressor, capacity and the team of mine rescue brigade (MRB) members to transport all equipment to the site of construction (3-4 people).

Therefore, to solve the problem of quick and reliable isolation of mine openings, the design of a new type of portable brattice, the basic structure of which is given in Fig. 1 [4, 5], was developed. Mathematical modeling of properties of the developed brattice is made for the conditions of mine openings passed by the Ural-20R combined machine, which are widely used at potash mines of Verkhnekamsk potassium-magnesium salt deposit.

The operating principle of the developed brattice is as follows.

The basic structure of the mine brattice (Fig. 1) is installed at the place of the brattice construction, and ski skids 2 and vertical rods 3 are attached to the base 1. Horizontal rods 4 and carriers 5 are attached to vertical rods 3. The brattice is constructed in a vertical position using the carriers, horizontal and vertical rods are extended along the mining opening section. After that, an air hose is inserted into the grooves 6, and a firefighting blanket is placed over the entire structure. The last two elements (firefighting blanket and air hose) are not shown in Fig. 1. Upon completion of the work, the air is supplied into the air hose, so that it inflates and presses the firefighting blanket placed on top of it against the walls, soil, and the roof of the mining opening.

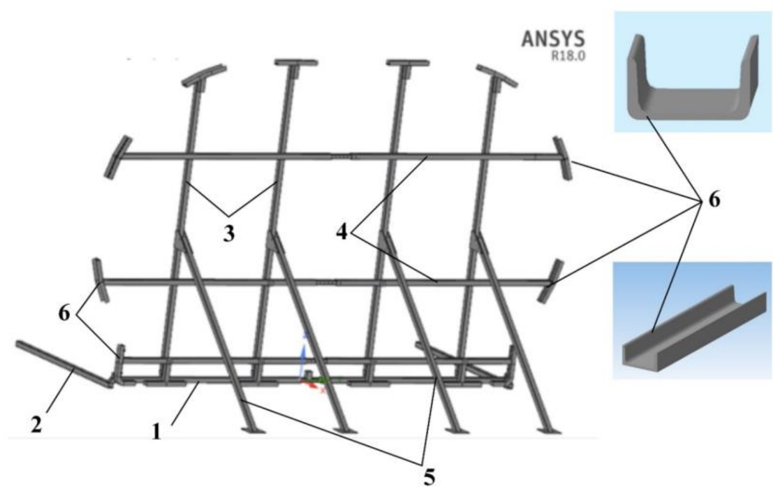


Fig. 1. The design of the mine brattice structure for the conditions of mine openings, passed passed by the Ural-20R combined machine: 1 - brattice base; 2 - ski skids; 3 - vertical rods; 4 - horizontal rods; 5 - carriers; 6 - grooves

In this case, the main cross-section of the mining opening will be shut off using a firefighting blanket, the pressure of the incoming airflow will be held by the brattice base structure, and insulation properties will be provided using an air hose, which mimics all the irregularities of the mining opening and presses the firefighting blanket against its surface.

Thus, a new type of the mine brattice will have the advantages of air bridges, using an air hose, which will also be able to smooth out all the irregularities in the cross-section of the mining opening, eliminating their main disadvantage - the need to fill the entire mine brattice with air.

To confirm the proposed theory, a pilot sample of a mine brattice manufactured on the basis of mathematical modeling was tested at an operating mine [5].

Tests were conducted at the BKPRU-2 operating potash mine (PAO "Uralkali").

During tests, the mine brattice was constructed in the chamber of the production unit (Fig. 2). Airflow from the booster fan (BF) was directed to the brattice. Air pressure and flow measurements were taken behind and in front of the mine brattice and adjacent mine openings.

a) *b*)

Fig. 2. Appearance of the mine brattice: *a* – upstream the air flow; *b* – downstream the air flow

As can be seen from Fig. 3, after pumping compressed air from the cylinder into the air hose, it tightly pressed the firefighting blanket against the walls, soil, and the roof of the mine opening.

a) *b*)

Fig. 3. Pressing the air hose: *a* – against the soil; *b* – against the wall of the mine opening

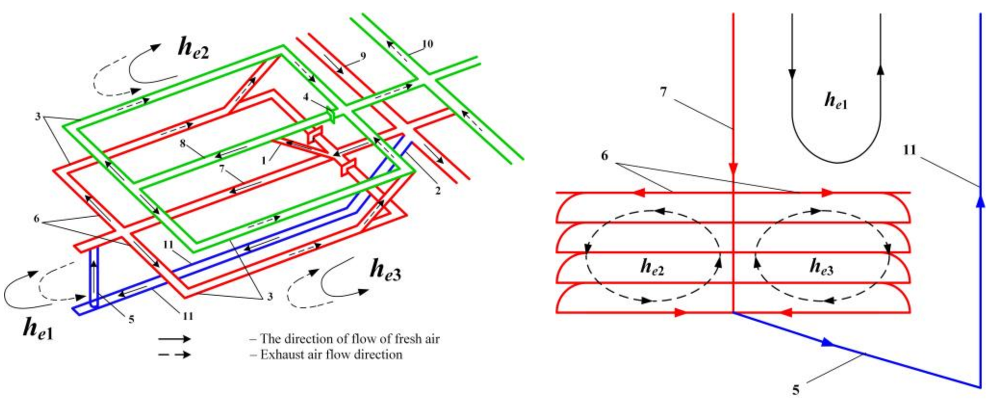
As a result of the tests carried out, it was found out that even when air is supplied through the booster fan duct (output velocity U = 11 m/s), the mine brattice does not let air through, i.e. reliably isolates the mine opening area. It took about 20 minutes to construct a brattice, and a cylinder with compressed air can be used for pumping.

3 Discussion

The air distribution in the production unit depends on the air-flow resistance of the mine openings, which varies as a function of their cross-section, length, and configuration, as well as the presence of heat sources and other factors specific to a particular type of shaft (mine). If during the development of ventilation method the factors that have the greatest influence on the air distribution are taken into account and used to improve ventilation conditions, it is possible to save energy resources spent on air supply to the working zone [4].

For potash mines with low air-flow resistance of mine openings [6, 7], the methods of ventilation of production units are suggested taking into account the action of thermal depressions (natural draughts) - the phenomenon caused by convective heat transfer, when warm air tends to rise and cold air - to fall [8-12].

For units of potash mines producing minerals through home mining, the ventilation scheme shown in Fig. 4 is applied. *a*. The direction of thermal depressions h_{e1}, h_{e2}, h_{e3} in the unit located updip, is shown in Fig. 4 *a* in continuous lines, i.e. they contribute to ventilation. In this case, there is no need to change the method of ventilation of the production unit. In case of downdip production unit mining, thermal depressions h_{e1}, h_{e2}, h_{e3} (in Fig. 4 *a* shown as dotted lines) act against the required direction of fresh airflow and, in some cases, reverse the airflow in the belt entry.



a) *b*)

Fig. 4. Simplified ventilation scheme for the block: *a* - the current scheme of unit ventilation; *b* - the proposed ventilation method of one of the unit horizons.
1 - slope on the AB layer; 2 - slope on the rock salt layer (belt entry); 3 - air drifts; 4 - brattice; 5 - blind shaft; 6 - chamber (mining); 7 - block haulage roadway in the Red-2 layer; 8 - block haulage roadway in the AB layer; 9 - panel haulage roadway; 10 - panel air drift; 11 - block belt entry.

In the ventilation method for the potash mine production unit located downdip, described in [13], it is proposed to pass air drifts on the length of the part of the panel (block) in which the second working is carried out, and the belt entry is used as ventilation (Fig. 4, *b*). However, the thermal depressions arising between the air and extraction drifts at the initial stage of mining (h_{e2} and h_{e3}) will be insignificant in size and will not be able to prevent the passage of air from the extraction drift directly into the belt drift. At the final stage of mining, when these thermal depressions are significant in size, contaminated air will begin to be recirculated into the mining chambers. To prevent such situations, a portable mine brattice is to be installed on the airflow path: at the initial (Figure 5, *a*) and final (Figure 5, *b*) stages of production unit mining. In such a ventilation scheme of the production unit, the energy-saving mode of ventilation will be provided by calculating the values of thermal depressions in advance and setting the stages at which the brattice is to be installed.

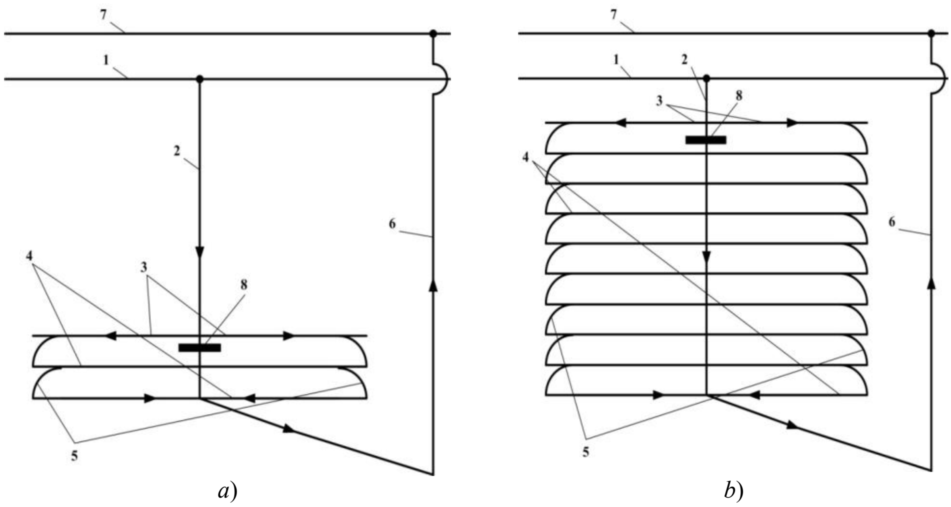


Fig. 5. Ventilation method of the production unit by means of home mining: *a* - initial stage of mining; *b* - final stage of mining.
1 - main haulage (panel) roadway; 2 - panel (block) extraction (haulage) drift; 3 - working chambers; 4 - abandoned chambers; 5 - panel (block) air drifts; 6 - buried panel (block) belt entry; 7 - main (panel) air drift; 8 - mine mobile brattice

In addition to energy efficiency, the proposed ventilation method should ensure safe mining operations. For example, in potash mines, in case of a fire in the block belt entry, which is the most possible place for an ignition, all the flue gases will be removed directly into the panel air drift, excluding flue gases from the working areas (Fig. 6, *a*). In this case, thermal depressions that arise between the block extraction drift in the AB layer (h_e), block extraction drift in the Red-2 layer (h'_e), and the belt entries will contribute to the removal of flue gases from the block.

In case of a fire in the block belt entry mined updip, thermal depressions h_e and h'_e can reach such a value that they will exceed the value of the mine ventilating pressure drop existing in the block (Fig. 6, *b*). This may cause the smoky air from the belt entry to enter the working chambers. To analyze the possibility of such a situation in the work, the process of thermal depression formation during a fire in the belt entry and their influence on air distribution in the block, located updip, has been simulated. As a result of research, it was found that in this case thermal depressions will really contribute to flue gas inflow into the bottom of the block mined updip.

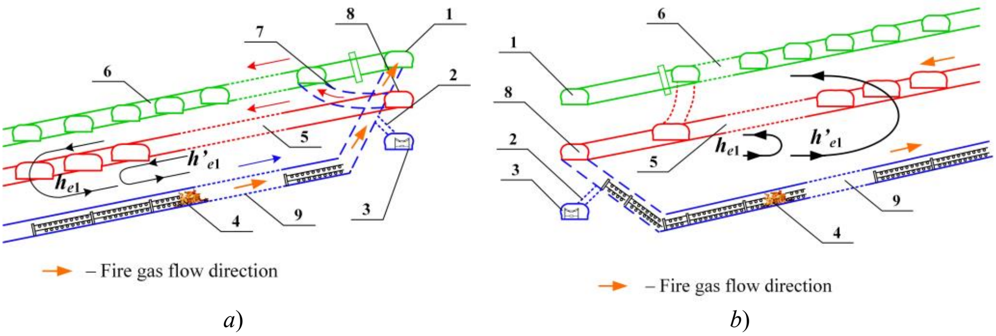


Fig. 6. Distribution of fire gases: *a* - in the block located downdip; *b* - in the block located updip. 1 - panel air drift; 2 - millhole; 3 - panel belt entry; 4 - conveyor belt ignition point; 5 - block haulage roadway (the Red-2 layer); 6 - block haulage roadway (the AB layer); 7 - slope; 8 - panel haulage roadway; 9 - block belt entry.

A portable brattice can also be used to prevent combustion products from entering the working zone (fig. 6, b). When it is used, the flue gases from the abandoned chambers will be evacuated into the block air drift and small amounts of gas-polluted air will flow through the brattice.

Particular attention should be paid to the fire resistance of the material from which it will be made during the design and subsequent use of the portable mine brattice. Either this brattice may be used in places where it will not be exposed to open fire or where it will be exposed to high temperatures that cannot be withstood.

The proposed variant of the mine brattice using a firefighting blanket located on top of the whole brattice structure allows placing the brattice in the high-temperature area.

4 Conclusion

As a result of testing a prototype of a new type of the mine brattice at an existing mine, it was found that the proposed device has the following advantages compared to the currently used air bridges:

1. Faster (about 20 minutes) construction to the working position. In this case, the construction of the brattice can be provided by and at the cost of miners, until the arrival of the mine rescue brigade (MRB). This is because bringing the brattice to the working position does not require special means (e.g., compressor), and a cylinder with compressed air can be used instead. A cylinder with 10 liters of compressed air is sufficient for 18-19 air hose pumpings.

2. Possibility of construction in the area of high temperatures (in the area of a fire). This property is achieved using a firefighting blanket located on top of the whole brattice structure.

Also, the mine brattice reliably isolates the mine opening without being inferior to the air bridges and can be used for several cross-sections due to the sliding structure elements.

These advantages of the mine brattice, when used in the above methods, will allow to control air distribution in the normal ventilation mode (energy saving) and protect miners in case of a fire.

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