Factors influencing strength and direction of natural ventilation pressure in general mines to control mine airing

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Abstract. The article presents three main factors, influencing the strength of natural ventilating pressure in general mines between the shafts: gas emission from mines (air density changes due to the change in concentration of other gases), changes of air parameters taken in by ventilating shafts, and air pressure due to the productivity shifts of the Main Fan Unit (or other devices for positive and negative control of air distribution). According to the experiment data the equations mentioned in other works for calculating natural ventilating pressure in general mines and taking into account the parameters of the air taken in are precise. Applying these formulas basing on the results of hydro meteorological forecast, whose accuracy in the short-term forecast is also high, it is possible predict the operating mode of the system of ventilation.

1. Introduction
During the underground mining it is necessary to ventilate the mines to provide safe working conditions for people. Main Fan Units (MFU) are applied in mines and shafts for this. They feed air down to shafts and mines into working zones. The number of production units, number of workers in a mine (shaft), gas volume and other factors determine an amount of air necessary to ventilate the underground mine. These factors determine the required capacity of a MFU. Ventilating practice shows that the volume flow of the air fed into the mine (shaft) changes constantly. One of the factors influencing significantly the ventilating process in underground mines is natural ventilating pressure in general mines between the shafts. When the natural ventilating pressure coincides with required direction of the air flow in the shaft it is called a positive natural ventilating pressure in a general mine. If it is reversed to the required air flow it is called a negative natural ventilating pressure and hinders the required ventilating process [5, 6].

Many works have been devoted to mathematical functions for determining the volume and direction of the natural ventilating pressure. M. V. Lomonosov was the first to pay attention to the natural ventilating pressure in mines. The first mathematical dependencies for determining the absolute values of the natural ventilating pressure in mines were introduced in [7-9]. The authors took into account the state of the atmosphere in a mine (shaft) which was considered in calculations as polytrophic, homogenous, isothermic and adiabatic, as well as mine depth and pressure developed by the MFU. Works [10, 11] take into account the influence of the natural ventilating pressure on air distribution in the system of ventilation. Authors of the consequent works analyzing the influence of different factors on the value of the natural ventilating pressure suggested both general and simplified formulas. For example, in [12] the authors considered that the natural ventilating pressure does not depend on the mine depth and MFU operation. In the article [13] it is stated that in the mine with a
single level shaft the natural ventilating pressure is initiated only by forced air supply that is with the
help of so called “air acceleration”. These articles also state that the natural ventilating pressure
increases with the shaft depth due to the air temperature increase and increases with the mine (shaft)
depth.

Thus, we can state that nowadays, there is no common point of view on the appearance of natural
ventilating pressure and factors influencing its magnitude and direction.

2. Results

Nowadays, there is no scientific explanation of the reasons of natural ventilating pressure occurrence
and regularities of changes in it, as well as its influence on the operation of MFU, which makes
impossible to create the methodology of monitoring the ventilating process of underground mines with
the account of its operation.

It can be noted that two factors influence the natural ventilating pressure – air density and the
variation between the spot height of the interconnected mines. We can make a conclusion that the
value of the natural ventilating pressure between the interconnected mines is influenced by the spot
heights which do not change relative to each other (for example, the shafts), only the air density will
have influence in these mines.

Three groups of reasons influence the changes in air density, consequently, the magnitude of
natural forces causing the displacement of air flows (masses):

1. Changes in air density at constant temperature and pressure, due to changes in gas concentration
   in the mine.
2. Air density changes due to its temperature fluctuation. The appearing draft in this case is called a
   “thermal drop of ventilation pressure”.
3. Changes in air density due to areas with increased or decreased pressure, which appear due to
   many reasons, such as: collision of air flows, redistribution in MFU reverso or changes in its capacity,
   when air flows runs onto artificial obstacles (shaft air bratices, air doors and so on).

Thus, to determine the factors influencing the value of the natural ventilating pressure it is
necessary to study separately the influence of these parameters on its value.

The article [14] provides the results of studying the changes in natural ventilating pressure values
depending on the gas concentration appearing while mining and influencing the air density in the
underground space. The authors conclude that the mechanism of natural ventilating pressure occurrence
between the underground mines will be different for gas-bearing and non-bearing mines. The authors
call this effect “gas ventilation pressure”. Mathematical functions have been received of density
difference dependence of “pure” air and gas saturated air on the value of natural ventilating pressure.
The studies have been carried out for the air standstill in the mine, when the pressure changes
(considerably, air density) is due to changes in concentration, that is when the air temperature is
constant. It can be stated that this article proves the fact of changes in natural ventilating pressure
when gases of the different density appear from the geological material (for example, methane). For
obvious reasons this factor is unique to gas bearing mines and shafts.

To determine the average air density in shafts versus its temperature and pressure, the paper [5]
introduces formulas. However, it was impossible to determine their accuracy till nowadays. It is caused
by the following challenge.

The ventilating process is slow responding – after shifts in MFU productivity air capacity in
downcast ventilating shafts will change only in some time [15]. After measuring air parameters in
airfeeding and ventilating shafts it is impossible to determine the reasons of air distribution changes
due to the difference of air capacity in the shafts. Due to this the article [16] suggests the calculation
method of the value and direction of the natural ventilating pressure measured at MFU. Here, when
MFU productivity changes the values of natural ventilating pressure \( h_e \) and air pressure of the mine
\( R_{\text{mine}} \) are determined by the least squares method the performance curves are built with and without
the account of this pressure.
The article gives the results of calculating natural ventilating pressure in general mines in summer and in winter with this method, the accuracy of the received data and their comparison has been done with the calculated ones according to operational formulas [5]. The experiments have been conducted at the mine PJSC “Uralkali”.

The calculation data by the method [16] of the air pressure of the mine \(R_{\text{mine}}\) with the account of (lines № 1 and 2) and without the account of (lines № 3 and 4) natural ventilating pressure \(h_e\) are in Table 1.

**Table 1.** The results of calculating the air pressure of the mine and natural ventilating pressure in general mines according to the experiment results (when MFU productivity changes)

| Parameter | The season          | \(R_{\text{mine}}\), (H\(\cdot\)s\(^2\))/m\(^8\) | \(h_e\), Pa  | \(h_{\text{lower}}\), Pa | \(h_{\text{upper}}\), Pa |
|-----------|---------------------|-----------------------------------------------|--------------|-----------------|-----------------|
|           | Summer experiment   | 0.01374                                       | 406.1        | 386.77          | 425.44          |
|           | Winter experiment   | 0.01686                                       | 75.99        | 66.80           | 85.18           |
|           | Summer experiment   | 0.01745                                       | –            | –               | –               |
|           | Winter experiment   | 0.01620                                       | –            | –               | –               |

Fig. 1 shows the mine curves by the determined values \(R_{\text{mine}}\) and \(h_e\): with the account of natural ventilating pressure (curve 1) and without it (curve 2). Figure 1 shows experimental points of the measured MFU operational modes at different speeds of rotor rotation (curve 3).

As graphs on Fig. 1 show the experimental points have more coincidents with the curves 1, that is with the curves, built with the account of the natural ventilating pressure in general mines. Here we can see that the experimental data, recieved in winter are not identical to the mine characteristic 2 as data in summer. In this case with the judicial probability we can suggest that in both experiments the air pressure of the mine \(h_e\) appeared but in winter its value was little. Table 1 shows that the values of the natural ventilating pressure were as follows: in summer \(h_e = 406.1\) Pa, in winter \(h_e = 75.99\) Pa.

### 3. Discussion

Taking into account the fact that the method of determining natural ventilating pressure at changes on MFU it is necessary to compare the recieved value of \(h_e\) with the recieved by formulas of operation [5] (let’s call them theoretical formulas). For this the parameters of the air outside were introduced into
the formula: temperature and air pressure. As in winter the air was dried (mine air heating installations), the air temperature in downcast ventilating shafts was measured by sensors inside them. The following data have been received.

In summer the value of natural ventilating pressure was \( h_e = 387.3 \text{ Pa} \), in winter \( h_e = 64.9 \text{ Pa} \).

Comparing the values \( h_e \), received in winter and in summer with the received by theoretical formulas values we can see that their variation is: 4.85% (summer) and 16.95% (winter).

In summer there the experimental points almost coincided with the characteristic curve of the mine built with the account of natural ventilating pressure (curve 1, Fig. 1, a). At this moment we can say that the natural ventilating pressure existed and its value was almost the same as received. The difference between the experimental value of the natural ventilating pressure in general mines and the one received by theoretical formulas is less than 5%.

The difference 16.95% is not so great, but we can suggest that this difference is due to poor convergence of the experimental data with the curve 1 (Fig. 1, b). Here, the winter data \( h_e \) can have some error. Perhaps this error influenced the difference of natural ventilating pressure values in winter and according to theoretical formulas.

In any case we can say that the theoretical formulas of operation [5] with high precision can be used for calculating the value and direction of the natural ventilating pressure.

### 4. Conclusion

The study has shown that to determine the value and direction of natural ventilating pressure it is necessary to take into account a gas presence in a mine. Changes in air density due to changes in gas concentrations in it will influence the natural ventilating pressure between the interconnected mines.

For mines with low volume of gas it has been determined that the value of natural ventilating pressure \( h_e \) with the high degree of accuracy can be determined by the derived formulas of operation [5], which can be separately used to determine the values of pressure and air temperature. Here we can determine the influence of these air parameters on the value of natural ventilating pressure separately.

It can be noted that the air parameters from hydrometeorologic forecasts can be introduced into these formulas. It has been proved that the accuracy of these forecasts nowadays is 85-90% [17, 18]. Consequently the obtained data can be used to calculate the predicted value of natural ventilating pressure, that allows to choose the required mode of MFU operation and the system of air drying beforehand (if it is necessary). It will allow controlling the ventilating process in a safe and energy saving mode.

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