# Factors defining value and direction of thermal pressure between the mine shafts and impact of the general mine natural draught on ventilation process of underground mining companies

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**Abstract.** The article specifies measuring data of air parameters and its volume flow in the shafts and on the surface, collected in BKPRU-2 (Berezniki potash plant and mine 2) («Uralkali» PJSC) in normal operation mode, after shutdown of the main mine fan (GVU) and within several hours. As a result of the test it has been established that thermal pressure between the mine shafts is active continuously regardless of the GVU operation mode or other draught sources. Also it has been discovered that depth of the mine shafts has no impact on thermal pressure value. By the same difference of shaft elevation marks and parameters of outer air between the shafts, by their different depth, thermal pressure of the same value will be active. Value of the general mine natural draught defined as an algebraic sum of thermal pressure values between the shafts depends only on the difference of temperature and pressure of outer air and air in the shaft bottoms on condition of shutdown of the air handling system (unit-heaters, air conditioning systems).

## Introduction

By extraction of mineral resources using underground method a ventilation of mining workings is necessary to provide safe working conditions of mine workers. For this purpose mines are equipped with main mine fans (GVU) which supply air through the shafts into working areas. Air volume required for ventilation of an underground mining company depends on the quantity of mining areas, the quantity of mine workers in the mine, gas content of the workings etc. Depending on these parameters a required GVU capacity is specified.

However volume flow of the supplied air changes continuously because the ventilation process is being influenced by the general mine natural draught (general mine thermal pressure) arising between the mine shafts as a result of the difference of air density in it. In case if a direction of the general mine natural draught coincides with the specified (required) direction of air circulation in the mine, the draught is specified as a positive general mine natural draught (general mine thermal pressure). If the general mine natural draught is directed opposite the air flow circulation, this phenomenon prevents from the normal ventilation mode – a negative general mine natural draught [1-6].

By certain conditions the negative general mine natural draught can achieve a value by which GVU will not be able to provide supply of the required air volume into the mine. Such a situation is unacceptable in terms of safety. In this case it is necessary to switch the fan operation to higher-pressure area which leads to the increase of its power consumption. It is unreasonable to hold a high GVU capacity continuously through the lens of economics due to heavy power costs spent on ventilation.

By action of the positive general mine natural draught on the contrary the mine will be supplied with larger air volume, so fan operation can be switched to lower-pressure area, i.e. the consumed power can be decreased.

The above-mentioned implies that a definition of the value of the general mine natural draught, its action direction as well as factors which influence on its value, is a critical task to settle out the issue of safety and energy efficiency of ventilation process in underground mining companies.

## Results and Discussion

Reasons of air circulation caused by convective heat transfer are known quite long ago. However there are different opinions by description of the impact degree of natural draught (thermal pressure) on the ventilation process in underground mining companies. For example, the paper [7] specifies a supposition that natural draught between the shafts can arise only if they are forcibly supplied with air, i.e. the draught alone is impossible without additional draught sources.

A supposition is often said that the mine depth and the value of the general mine natural draught are interrelated. The papers [8, 9] suggest that due to the increase of air temperature with the increase of the shaft depth the natural draught also rises, i.e. the deeper the mine the higher the draught. According to the paper [7] the natural draught has no special impact on the ventilation process because great depth results in the high value of the shaft air-flow resistance. In this case it is supposed that the considerable natural draught between the mine shafts is compensated due to their high air-flow resistance.

To identify actual factors which influence on the value of the general mine natural draught between the shafts and accordingly to analyze its impact degree on the ventilation process, measurements by GVU shutdown have been performed in BKPRU-2 mine («Uralkali» PJSC»).

Table 1 specifies the measurements results where $t_н$, $t_1$ ,$t_2$, $t_3$ are temperatures accordingly of the outer air, air in the shafts №1, 2 (air inlet shafts) and 3 (ventilation shaft), ºC; $P_a$ is air-pressure, mm of mercury; $P_1$, $P_2$, $P_3$ is pressure in the shaft bottom accordingly of the shafts № 1, 2, 3, mm of mercury; $Q_1$,$Q_2$,$Q_3$ is volume air flow accordingly in the air inlet shafts № 1, 2 and in the ventilation shaft № 3.

**Table 1.** Air parameters obtained as a result of the measurements in BKPRU-2 mine («Uralkali» PJSC)

| № p/p | Measurement time | Outer air parameters | | Air parameters in the shaft № 1 | | | Air parameters in the shaft № 2 | | | Air parameters in the shaft № 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $t_н$. ºC | $P_a$. mm of mercury | $t_1$. ºC | $P_1$. mm of mercury | $Q_1$. $m^3/s$ | $t_2$. ºC | $P_2$. mm of mercury | $Q_2$. $m^3/s$ | $t_3$. ºC | $P_3$. mm of mercury | $Q_3$. $m^3/s$ |
| 1 | 22.00 | 13.2 | 730.712 | 17.6 | 776.635 | 167.78 | 17.3 | 777.181 | 169.15 | 15.3 | 774.156 | 336.77 |
| 2 | 22.20 | 13.4 | 731.112 | 18.1 | 769.157 | 88.74 | 18.3 | 770.230 | 91.14 | 16.0 | 764.232 | 179.79 |
| 3 | 22.40 | 13.6 | 731.798 | 19.5 | 765.655 | -22.56 | 19.3 | 765.625 | 15.18 | 16.9 | 753.811 | -37.63 |
| 4 | 23.20 | 14.1 | 732.120 | 19.7 | 765.232 | -28.08 | 19.4 | 765.132 | 10.89 | 16.3 | 753.123 | -44.14 |
| 5 | 23.40 | 13.6 | 732.090 | 19.7 | 765.528 | -30.48 | 19.5 | 765.311 | -13.20 | 16.5 | 754.203 | -43.15 |
| 6 | 00.20 | 14.3 | 732.038 | 18.9 | 765.208 | -27.36 | 19.5 | 765.104 | -12.21 | 16.3 | 754.158 | -38.73 |
| 7 | 00.40 | 13.8 | 731.798 | 19.3 | 765.383 | -27.36 | 19.7 | 765.243 | -12.87 | 16.5 | 754.324 | -37.98 |
| 8 | 01.20 | 13.3 | 731.813 | 18.7 | 765.535 | -26.16 | 19.5 | 765.510 | -12.21 | 16.2 | 754.218 | -40.23 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 01.50 | 13.4 | 731.843 | 19.3 | 765.631 | -28.32 | 19.0 | 765.588 | -12.87 | 16.6 | 753.712 | -41.65 |
| 10 | 02.10 | 13.3 | 731.821 | 18.9 | 765.581 | -27.84 | 19.0 | 765.107 | -12.54 | 16.2 | 754.213 | -37.89 |
| 11 | 02.40 | 13.2 | 731.798 | 18.7 | 765.231 | -28.08 | 18.8 | 765.144 | -9.9 | 16.4 | 753.121 | -40.18 |
| 12 | 03.00 | 13.1 | 731.760 | 18.7 | 765.357 | -27.84 | 19.1 | 765.223 | -11.22 | 16.2 | 754.212 | -41.35 |
| 13 | 03.30 | 13.4 | 731.655 | 18.9 | 765.325 | -29.76 | 18.7 | 765.217 | -11.22 | 16.1 | 754.209 | -43.36 |
| 14 | 04.10 | 13.5 | 731.663 | 18.8 | 765.403 | -28.32 | 18.9 | 765.364 | -11.88 | 16.4 | 754.201 | -41.30 |

The GVU shutdown was carried out at 22.00 (line 1, table 1).

As is seen from the table, at this moment the shafts were supplied with the air volume sufficient for the normal operation mode of the mine. In 20 minutes the volume air flow supplied to the underground mining workings decreased approximately two times, and in another 20 minutes changed its direction to the contrary.

The air circulation was continuous for 6 hours, i.e. all the time the ventilation was produced due to the general mine natural draught.

Based on the performed measurements authors of this paper have supposed as follows:

1. The general mine natural draught ($h_e$) due to which ventilation was produced by the GVU shutdown, and which influences on the ventilation process by its operation, depends on the mutual action of thermal pressure between each pair of the interconnected shafts (Figure 1).

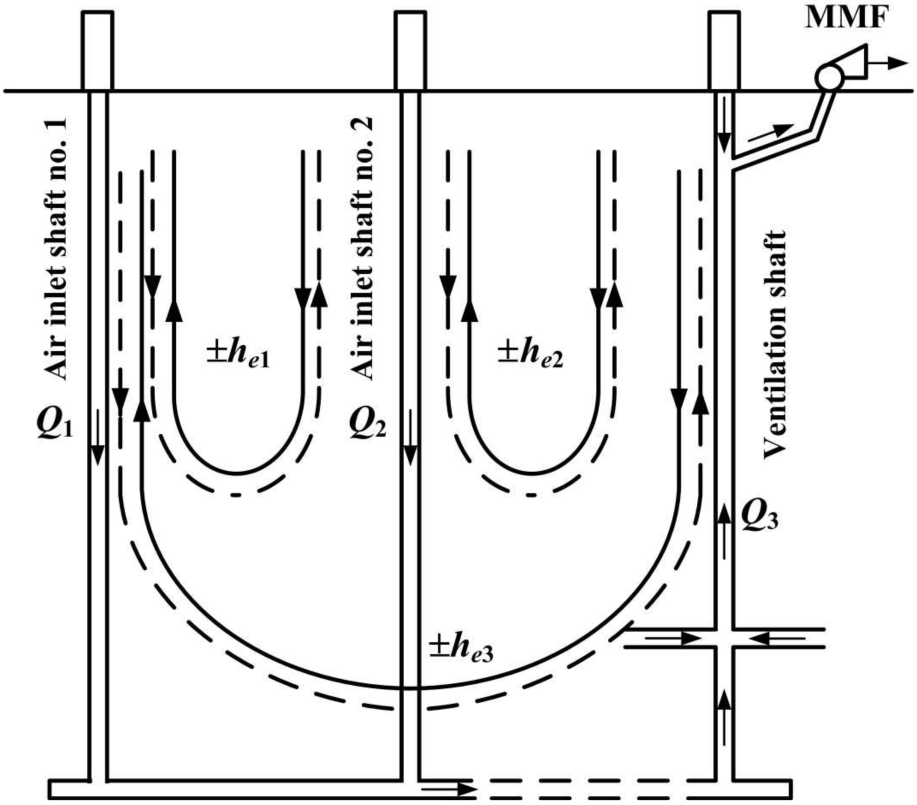


**Figure 1.** Simplified schematic of ventilation of BKPRU-2 mine (with two air inlet shafts, exhaust system of ventilation)

According to the paper [10] the value of the general mine natural draught is defined as an algebraic sum of all thermal pressure values between the shafts $h_{å} = \sum_{i=1}^{n} h_{å,i}$ (where *n* is a quantity of the mine shafts) considering the difference of elevation marks of the shaft mouths.

As a result of the calculations it became clear that by the mine ventilation and after the GVU shutdown the negative general mine natural draught between the shafts was active which was directed opposite the air circulation through the shafts. Although due to that the GVU pressure was much higher than the arising draught, the air was supplied to the shafts in the required volume.

After the GVU shutdown the fan-made pressure decreased and the general mine natural draught remained negative and almost did not change its value.

At some time (22.20 – 22.40 period) a reverse of the air stream occurred, i.e. ventilation of the underground mining company started only due to the general mine natural draught after the full stop of the air circulation (the moment of the direction change). No additional draught sources were needed for that.

Volume air flow measured in real conditions differs from the calculations results (according to the mathematical relations of the paper [10]) within 2-3%. Besides, it has been established that the general mine natural draught actually equals to the algebraic sum of thermal pressure between the shafts.

2. Thermal pressure between the shafts is continuous regardless of the ventilation mode. Only two factors have an impact on the pressure value – the difference of temperature and pressure of the outer air and the air in the shaft bottoms.

Such a conclusion has been made on the basis that the values of thermal pressure between the shafts and accordingly the values of the general mine natural draught were almost stable by operating GVU, after the stop of the forced ventilation and for several hours. It could be caused by a small change of the outer air parameters. If we compare the air pressure value in the shaft bottoms by the GVU operation and after its shutdown, it can be seen that the parameters difference is quite considerable. Although the difference between the values in the shafts was almost stable. Thus, the GVU operation mode has almost no impact on the value of the general mine natural draught. On that basis it can be supposed that the air pressure and temperature in the shaft bottoms will increase by changing the shaft depth, and the difference of these values are not to change considerably. In this case it can be said that the shaft depth is also not a parameter which influences on the value of the general mine natural draught by ventilation of the underground mining company.

3. The single case of absence of the general mine natural draught between the shafts is location of all the shaft mouths on the same elevation mark on surface and location of the shaft low points (shaft bottoms) on the same level.

Such a situation in real conditions is almost impossible, consequently the general mine natural draught between the shafts will be always active. Another issue is that its value can be neglected by low elevation differences.

In this case the value of the general mine natural draught will rise if there are more differences between the outer air parameters and the parameters on the mine stratum depth.

## Conclusion

Due to that the general mine natural draught has a strong effect on the GVU operation in some cases, it is necessary to consider the draught action by ventilation process. Based on the performed experimental research it has been found that the general mine natural draught is active between the mine shafts continuously, and its value depends on the outer air parameters and the air parameters in the shaft bottoms. Thermal pressure equal on the value and direction will be active between the shafts of the same mine by the same specified air parameters regardless of the GVU operation mode. However it is necessary to take into account that such a situation will arise only by power-off air handling system (unit-heaters, air conditioning systems).

Thus, the value of thermal pressure which will be active between the shafts, can be defined for each certain mine using the outer air parameters and the air parameters in the shaft bottoms. Having defined the value of the general mine natural draught as an algebraic sum of thermal pressure between the shafts, it is possible to provide the GVU operation when the underground mining company is supplied with the required air volume by minimum power costs for ventilation. Thanks to similar research for the mines by operation of the air handling systems, the power saving mode of ventilation can be set up due to the change of the GVU operation mode considering the effect of the general mine natural draught year-round.

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