DE GRUYTER
OPEN

Arch. Min. Sci., Vol. 59 (2014), No 2, p. 501–508

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.2478/amsc-2014-0036

PAVEL ZAPLETAL*, VLASTIMIL HUDEČEK*, VITALY TROFIMOV**,

EFFECT OF NATURAL PRESSURE DROP IN MINE MAIN VENTILATION

SKUTKI NATURALNEGO SPADKU CIŚNIENIA W GŁÓWNEJ SIECI WENTYLACYJNEJ KOPALNI

Natural ventilation in a mine is ventilation without the use of means of artificial ventilation. The flow of mine air is induced by the difference between the mass column in an intake and that in a return. The difference in mine air density is a result of difference between the temperature of intake air and that of return air. To a certain extent, the influence of differences in mine air humidity and chemical composition can act as well.

Gassy mines in the Czech Republic and Ukraine are ventilated merely artificially, i.e. by means of exhaust ventilation. However, even in the case of this type of ventilation, when the total mine air flow is produced by fans, a natural current of air exists and acts in the ventilation network of the mine.

Keywords: Mine ventilation, natural pressure drop, temperature, main fan

Naturalna wentylacja w kopalni to wentylacja bez wykorzystania środków sztucznej wentylacji. Przepływ kolumny powietrza wymuszony jest poprzez różnicę ciśnień pomiędzy kolumną powietrza na wlocie a prądem zużytego powietrza. Różnica w gęstości powietrza kopalnianego wynika z różnicy temperatur pomiędzy powietrzem wlotowym i zużytym. W pewnym stopniu uwidacznia się także wpływ wilgotności powietrza kopalnianego i jego składu chemicznego.

Kopalnie gazowe w Republice Czeskiej i na Ukrainie są przewietrzane przy użyciu sztucznej wentylacji, z wykorzystaniem instalacji wyciągowej. Jednakże nawet w przypadku zastosowania tego typu systemu wentylacyjnego w którym przepływ powietrza kopalnianego w całości generowany jest przez wentylatory, nadal istnieją naturalne prądy powietrza, których obecność i działanie ujawnia się w sieci wentylacyjnej.

Słowa kluczowe: wentylacja kopalni, naturalny spadek ciśnienia, temperatura, wentylator główny

* VSB – TECHNICAL UNIVERSITY OF OSTRAVA
** DONECK NATINONAL TECHNICAL UNIVERSITY

Introduction

When passing through the mine and imaginarily back through the surface atmosphere, the mine air undergoes a reversible change. From the atmosphere the air of temperature T_0 and pressure p_0 flows to the mine where the mentioned state quantities gradually change to T_1 up to T_n and p_1 up to p_n. The air exiting the mine mixes with the atmospheric air and, with regard to the disproportionately larger volume of the atmospheric tank that can be taken with reference to the small amount of mine air as infinite, the initial temperature T_0 and pressure p_0 of air remain constant. The thermodynamic cycle is thus closed and then repeated again (Suchan, 1984).

The natural current as well as the pressure drop produced by the main fan is a source of energy for the flow of air in the mine. The natural current pressure drop is positive if the current operates synergistically with the fan and the drop is negative if it operates non-synergistically with the fan.

1. Activation at Combination of Fans I and II in Series

The activated characteristic $(AB)_{AS}$ at eliminating a fan connected in series (e.g. I) is obtained by deducting relevant ordinates of the characteristic of fan I $(p - Q_v)_1$ from individual ordinates of the characteristic of segment AB $\Delta p_{AB} = R_{AB} \cdot Q_v^2$.

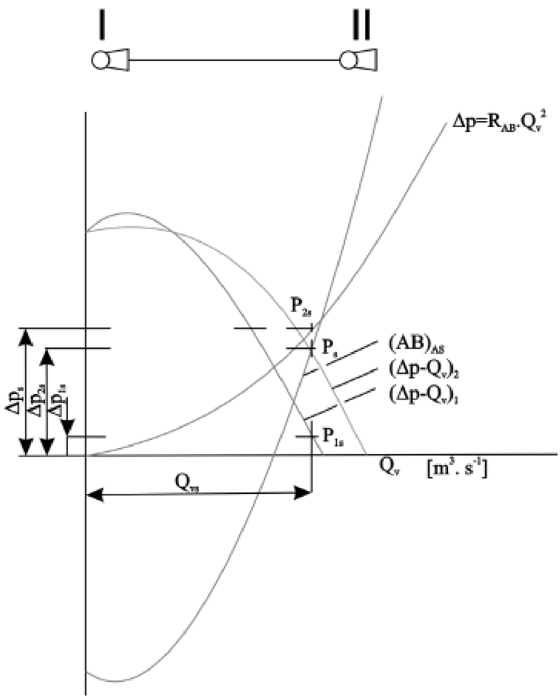

Fig. 1. Activation at combination of fans I and II in series

The intersection of the activated characteristic $(AB)_{AS}$ with the characteristic of fan II $(p - Q_v)_2$ will be designated P_S; this is the operating point that determines the conditions of combination of fans I and II.

The ordinate of point P_S represents the volume flow rate Q_{vs} in the segment AB. A parallel to the axis of ordinates, running through the point P_S, will intersect the characteristic $(p - Q_v)_1$ at the point P_{1S} and the characteristic $\Delta p_{AB} = R_{AB} \cdot Q_v^2$ at the point P_{2S}. The ordinate of point P_S gives the pressure gradient Δp_{2S} produced by fan II, the ordinate of point P_{1S} gives the pressure gradient Δp_{1S} produced by the fan I and the ordinate of point P_{2S} gives the pressure gradient Δp_S, if the air with the volume flow rate Q_{vs} flows along the segment AB.

2. Activation at Parallel Combination of Fans I and II

The activated characteristic $(AB)_{AP}$ at eliminating a fan connected in parallel (e.g. II) is obtained by deducting relevant segments of the characteristic of fan II $(\Delta p - Q_v^2)_2$ from individual segments of the characteristic of segment AB $\Delta p_{AB} = R_{AB} \cdot Q_v^2$.

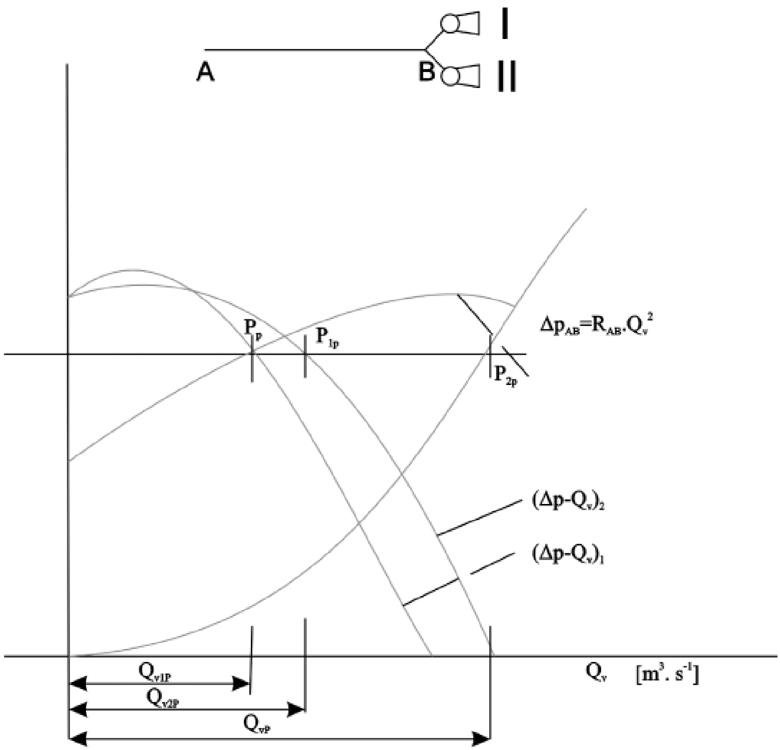

Fig. 2. Activation at parallel combination of fans I and II

The intersection of the activated characteristic $(AB)_{AP}$ with the characteristic of fan I $(p - Q_v)$ will be designated P_P. A parallel to the axis of the segments passing through the point P_P intersects the characteristic of fan II $(\Delta p - Q_v)_2$ at the point P_{1P} and the characteristic of the segment $\Delta p_{AB} = R_{AB} \cdot Q_v^2$ at the point P_{2P}. The ordinate of point P_P gives the volume flow rate Q_{v1P} of fan I, the ordinate of point P_{1P} then the volume flow rate Q_{v2P} of fan II and the ordinate of pointt P_{2P} gives the overall volume flow rate Q_{v2} in the segment AB.

The ordinate of point P_P gives the pressure gradient Δp_P in the segment AB and pressure gradients caused by the fans. (Prokop et al., 1985, 2011)

3. Replacement of a Fan by a Natural Source of Pressure Drop

When one of the fans is replaced by a natural source of pressure drop, a combination of the fan and the source of natural pressure drop can be dealt with. The characteristic of the source of pressure drop is represented in the diagram $\Delta p - Q_v$ as a parallel to the axis Q_v at a distance of the given value of Δp.

Then three cases of interaction between the main fan and the source of natural pressure drop (natural pressure drop = NVP) may occur.

(1) NVP acts synergistically with the main fan,
(2) NVP acts non-synergistically – against the action of the main fan,
(3) The value of NVP is so small that it will not affect the work of the main fan.

In Figure 4 we can see the activated characteristic (auxiliary activated curve NVP = –320 Pa) and the representation of the operating point on the operating characteristic of the fan.

We can see that the operating point will move by the activation of the mine characteristic by 320 Pa downwards. This means that the fan only needs "to produce a pressure drop by 320 Pa smaller" to produce the required volume air flow rate (Kopáček, 2003).

In addition to the aerodynamic resistance of mine workings themselves, the main mine fan has to overcome the aerodynamic resistance of the air duct, the internal resistance of the fan itself and the aerodynamic resistance of the diffuser. The total negative pressure that has to be produced by the fan is then given by the following relation Δp_c

$$\Delta p_c = \Delta p_{dd} + \Delta p_k + \Delta p_v + \Delta p_d \pm \Delta p_n \quad \text{[Pa]} \tag{1}$$

where:

Δp_c — total negative pressure, [Pa],
Δp_{dd} — pressure gradient required for overcoming the total aerodynamic resistance of mine workings, [Pa],
Δp_k — pressure gradient required for overcoming the resistance of the air duct, [Pa],
$\pm\Delta p_n$ (NVP) — pressure gradient due to the natural pressure drop, [Pa],
Δp_v — pressure gradient necessary for overcoming the internal resistance of the fan together with the resistance of the noise damper and diffuser chamber.

To the consumption of negative pressure we have to add the value of dynamic (velocity) component of pressure during the exit of air masses to the atmosphere, and this is given by the following relation:

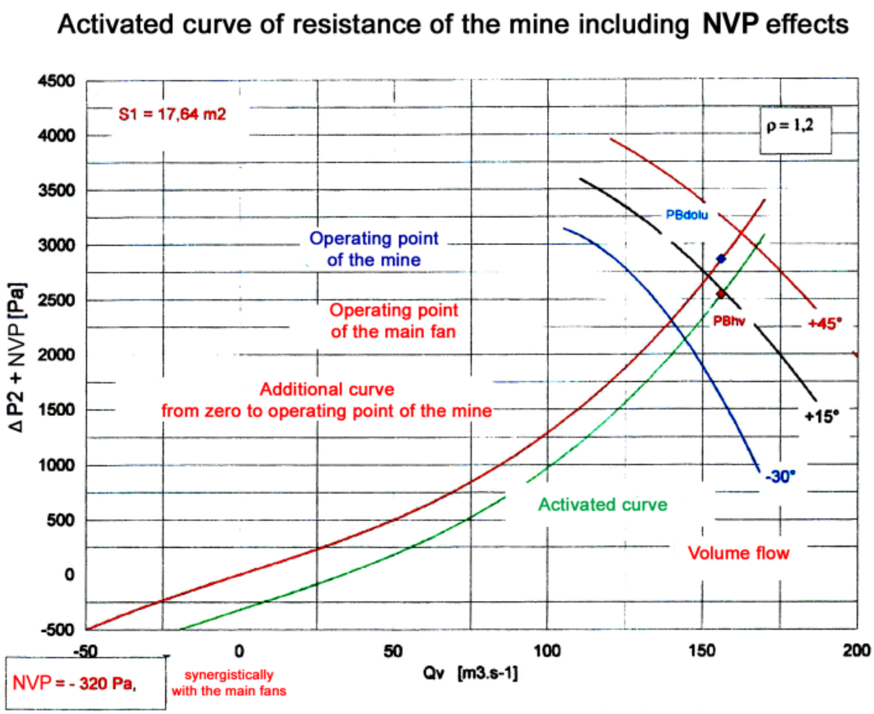

Fig. 3. Activated curve of resistance of the mine including NVP effects (Kopáček, 2003)

$$\Delta p_d = \frac{v^2 \rho}{2} \quad [\text{Pa}] \tag{2}$$

where:

v — velocity of mine air exiting to the atmosphere, $[\text{m} \cdot \text{s}^{-1}]$,
ρ — density of return air moved by the main fan, $[\text{kg} \cdot \text{m}^{-3}]$.

The magnitudes of the values of individual resistances have the decisive influence on the work of the main fan. That is why it is necessary to form, as early as during the stage of planning, preconditions for as small as possible aerodynamic resistance of the air duct. This can be achieved by shortening the length of the duct, by gradual non-sharp changing the direction of air flow in air channels, by slow changing the shape of air channels when dividing the air flow into parallel branches, etc. (Skoczylas, 2012)

4. Model Situation of Combination of Natural Air Current and Mine Main Ventilation

On the basis of measured values from the Karviná Mine, ČSA plant, we analysed model situations for the combination of natural air current and mine main ventilation (Zapletal, 2009).

For the analyse we used polish software Ventgraph (Dziurzynski et al., 2009, 2011). This program is used for the ventilation network calculations in the normal conditions and the anomalous conditions, like a mine fire, or methane exhalations. (Hudeček, 2008) The basic parameters for this analysis were measured values of dry temperatures and compressible calculation of the ventilation network.

Surface temperature:		18.8°C,
Relative humidity:		51%,
Barometric pressure:		102000 Pa,
Fan pressure drop – upcast shaft:	ČSA 3	3169 Pa,
	Doubrava III	2727 Pa,
	Eleonora	3020 Pa.

TABLE 1

Table of part of calculation at temperature of 18.8°C and initial pressure drop of fans

Branch no.	Nodal point 1	Nodal point 2	ρ $[kg \cdot m^{-7}]$	Q_v $[m^3 \cdot s^{-1}]$	Δp [Pa]
0	1	1A	1.21	212.3	0
1	1A	2	1.24	207.3	565.4
2	2	3	1.28	196.1	150.4
3	3	4	1.30	162.8	57.5
4	3	7	1.29	6.2	10.2

The following table shows a change in mine air density ρ, volume flow rate Q_v and pressure drop Δp at a change in temperature in two intake nodes (at the nodal point 1A from 18.8°C to -5°C and at the nodal point 2 from 21°C to -2°C)

TABLE 2

Table of part of calculation at partial change in temperature and initial pressure drop of fans

Branch no.	Nodal point 1	Nodal point 2	ρ $[kg \cdot m^{-7}]$	Q_v $[m^3 \cdot s^{-1}]$	Δp [Pa]
0	1	1A	1.33	257	0
1	1A	2	1.36	250.3	824.6
2	2	3	1.34	244.2	233.2
3	3	4	1.30	202.7	88.8
4	3	7	1.29	4.7	147.3

Surface temperature:		–5°C,
Relative humidity:		51%,
Barometric pressure:		102000 Pa,
Fan pressure drop – upcast shaft:	ČSA 3	2535.2 Pa,
	Doubrava III	2181.6 Pa,
	Eleonora	2416 Pa.

TABLE 3

Table of part of calculation at partial change in temperature and at reduction in pressure drop of fans by 20%

Branch no.	Nodal point 1	Nodal point 2	ρ [kg · m⁻⁷]	Q_v [m³ · s⁻¹]	Δp [Pa]
0	1	1A	1.33	242.8	0
1	1A	2	1.36	236.6	736.4
2	2	3	1.34	230.5	207.7
3	3	4	1.30	190.4	78.7
4	3	7	1.29	23.4	146.2

From the following tables Tabs. 1, 2 and 3 it is evident that the program Ventgraph can also be used for the control of pressure drops of main fans at a change in air temperature. It could be used profitably in the case of combination of mine main ventilation and natural air current. The comparison of Tables 1 and 2 shows that at a change in surface temperature, pressure drops in the network branches and volume flow rates of air will increase due to the natural air current. If we however decrease pressure drops of main fans (e.g. by 20%), then at keeping the decreased temperature, a reduction in pressure drops at nodal points and in volume flow rates will occur. (Gacek et al., 2007)

5. Actual Thermal Buoyancy and Average Temperatures

To verify the previous considerations, we compared the true values from the ventilation balances of still active mines. In the following table, the amount of the natural pressure drop Δp_{ter} at various decisive quantities, such as static pressure Δp_{st}, surface temperature and volume flow rate Q_v is clear.

TABLE 4

Thermal buoyancy

Mine – upcast shaft	Pressure drop measurement	NVP [Pa]	Surface temperature	Δp_{st} [Pa]	Q_v [m³ · s⁻¹]
ČSM – Jih	May	**–136**	14,5°C	2750	309
ČSM – Sever	May	**–242**	15°C	2650	315
DARKOV – Mír 4	May	**–190**	15°C	2786	433
DARKOV – Su-Sto III	May	**–132**	12°C	1916	230
KARVINÁ – ČSA 3	May	**–470**	17,5°C	3875	258
KARVINÁ – Do-III	May	**–360**	17,5°C	2698	145
KARVINÁ – Lazy	June	**–75**	22°C	2089	300
PASKOV – Sviadnov	October	**–230**	3,5°C	2580	136
PASKOV – Staříč	October	**–305**	3,5°C	3178	219
PASKOV – Chlebovice	October	**–205**	4,5°C	2990	218

It can be deduced from Table 4 that thermal buoyancy in mines being compared acts synergistically with the main fans.

6. Conclusion

An important condition for the calculation of ventilation network with the use of artificial ventilation and natural air current and control of pressure drops caused by main fans is the consideration of a possible change in temperature at all nodal points, especially then at the nodal points of main downcast and upcast shafts. Thus the overall influence of natural ventilation on the whole ventilation network will manifest itself.

Mine ventilation is a very important parameter of active mines and costs of mine ventilation themselves are usually a very significant item of the overall costs of the mine. If the natural air current was reasonably used in mine ventilation, a reduction in electrical energy consumption could be achieved, because fans would not work at their usual performance and thus also the costs of mine ventilation itself could be decreased.

References

Dziurzynski W., Krach A., Palka T., 2009. *Method of Regulating Elements of the Methane Drainage Network Using Computer Simulation*. Arch. Min. Sci., Vol. 54, No 2, p. 159-187.

Dziurzynski W., Kruczkowski J., 2011. *Variability of the volumetric air flow rate in a mine fan channel for various damper positions.* Arch. Min. Sci., Vol. 56, No 4, p. 641-650.

Gacek Z., Olajossy A., 2007. *Material balance in a pseudo-steady state of natural gas flow.* Arch. Min. Sci., Vol. 52, No 2, p. 171-193.

Hudecek V., 2008. *Analysis of Safety Precautions for Coal and Gas Outburst – Hazardous Strata*. Journal of Mining Science, Vol. 44, No 5, p. 42-50.

Kopáček F., 2003. *The cooperation of the pressure sources with the subsurface ventilation*. Associate professor thesis, VŠB – TU Ostrava.

Prokop P. et al., 1985. *Ventilation of deep mines*. VŠB – TU Ostrava, textbook, 1985.

Prokop P., Zapletal P., Pegrimek I., 2011. *Prognosis of residual coal gas capacity made by the "express" method*. International Journal of Minerals, Metallurgy and Materials, 18 (2011), No.2, p.127.

Skoczylas N., 2012. *Coal seam methane pressure as a parameter determining the level of the outburst risk – laboratory and in situ research.* Arch. Min. Sci., Vol. 57, No 4, p. 861-869.

Suchan L., 1984. *Deep Mine Ventilation*, Libor Suchan, Prague 1984.

Zapletal P 2009. *Proposal for Principles of Control of Ventilation Network in a Fire-Affected Area*. Ph.D. thesis, VŠB – TU Ostrava.

Recveived: 19 August 2013