MODELLING OF GAS COMMUNICATIONS WITH APPLICATION TO ABANDONED IDA MINE IN OSTRAVA-KARVINA COALFIELD

MODELOVÁNÍ PLYNOVÝCH KOMUNIKACÍ S APLIKACÍ NA UZAVŘENÝ DŮL IDA V OSTRAVSKO-KARVINSKÉM REVÍRU

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Abstract

Protection of building objects regarding a possible gas escape from closed mine excavations to the surface is a problem we can see in OKR very often. To prevent successfully gas emission it is necessary to specify a methodical procedure of this risk solution. Implementing such procedure is increasingly needful especially considering reducing mining in OKR and thus uncontrolled gas emission from these areas. At first, we need to determine the value of residual gases emission. According to this value we then determine the manner of enclosure. Two possibilities are introduced in the paper. We can use either the way, in which the gas will be taking away from settlement by means of boreholes or better by methane drainage pipeline. The better possibility is leaving the drainage pipeline in the shaft before filling, through which we can take away the residual coal gas capacity.

Abstrakt

Ochrana stavebních objektů vzhledem k možnému výstupu metanu z uzavřených důlních děl je problém, se kterým se lze v ostravsko-karvinském revíru setkat velmi často. Aby boj s metanem vystupujícím na povrch mohl být úspěšný, je třeba stanovit metodický postup řešení tohoto rizika. Nutnost stanovování této metodiky se stává více a více potřebná, především vzhledem k utlumující těžbě v OKR a tím i k nekontrolovatelnému výstupu metanu z těchto prostor. Nejprve musíme určit množství výstupu metanu. V souladu s výší emise určíme způsob uzavření. Tento příspěvek předkládá dvě možnosti. Jednou z nich je způsob, kdy můžeme vystupující metan čerpat vrty nebo lépe plynovým potrubím. Vhodnějším způsobem se jeví možnost ponechání degazačního potrubí před samotným zásypem jámy, kterým lze odvádět zbytkovou plynodajnost.

Key words: uzavřený důl – abandoned mine, výstup plynu – gas emission, plynodajnost – coal gas capacity

1 INTRODUCTION

The problem of gas emission from the closed underground to the surface caused and causes in Ostrava-Karvina Coalfield (OKR) a series of issues. In this paper I would like to attend to the situation, when after closing shafts in the area of the Ida mine relatively dangerous leakages of mine gases with a high concentration of methane occurred. I have solved this case especially with respect to endangering building objects on the surface. I present a procedure, when using the GrafSit computer program the mentioned risk can be analyzed and results can be acquired allowing determining a correct way of protection.

2 PROBLEM SOLUTION PROCEDURE

For network of gas communications according to [1] I performed in GrafSit different variants of calculations of supposed flow of the mine atmosphere in the closed environment.

The diagram of gas communications is given in Fig. 1.

I proceeded from the data stated in [1], according to which in the surrounding of the Ida shaft the mine atmosphere with a high concentration of CH_4 accumulated in soil. This situation is given according to results of atmogeochemistry in Fig. 2.

Carrying out the calculation for the abandoned mine environment is a relatively complicated problem. To calculate a classical wind network it is necessary to know input parameters like these:

- pathways resistances

- depressions.

In the abandoned mine environment acquiring such data is a very difficult task. Therefore I used further findings being gathered in [2]. In [2] there is given a set of results, based on which a gas balance was found out in different mines of Ostrava-Karvina Coalfield (OKR). The Ida Mine, whose solution I present here (as it is known, it was later renamed to the Hermanice Mine) and whose gas balance is also involved in [2]. I used the value of the gas balance acquired during the mine operation and derived a probable amount of the gas balance of the abandoned mine. The term "residual coal gas capacity" has been recently started to be used for it.

Further I obtained pressure values at the methane drainage borehole nearby the Ida shaft. This borehole was later flooded and so it could not carry out the degassing function.

The calculation in the GrafSit program is static. To display the state of the highest risk, I modelled the situation, when the lowest barometric pressure takes effect and for this case I used the value of difference in pressure between the closed underground (mine) and surface.

It is understandably too problematic how to derive from two inputs, i.e. depression and volumetric flow rate (emission) of the mine atmosphere, resistances in the network of gas communications.

However GrafSit allows very fast editing, so that I came, by changing great number of input parameters and using the CPM method, to distribution of resistances that with a high probability expresses the real situation in the closed underground.

I was grounded on the known facts, which were especially real situations nearby all closed shafts. Upon their closing and obviously upon probable communication along the system of initial galleries such state occurred when

- nearby the abandoned Ida shaft the mine atmosphere came up to the surroundings and the range of risk was relatively reliably monitored
- nearby other shafts (see Fig. 1) owing to the resistance along pathways and owing to the way of their closing, the mine atmosphere emission to the neighbourhood was not registered.

The real situation and results of the mentioned models prove that the initial skeleton of galleries after closing the mine and by pressure effect of main mass of mountains kept a certain throughput. Resistances along these damped pathways are against the initial ones of course dramatically higher.

To determine the value of a damped pathway (GrafSit uses the denotation „r“) I used two methods. For the first approximation it was the relation known from the underground ventilation, where the pathway resistance R is being determined as

$$R = \frac{\alpha \cdot L \cdot U}{S^3} \quad \left[kg \cdot m^{-7}\right]$$

where:

R – frictional resistance $[-]$,

α – coefficient of friction $[-]$,

L – pathway length $[\mathrm{m}]$,

U – mine excavation circumference $[\mathrm{m}]$,

S – cross section area of mine excavation $[\mathrm{m}^2]$

For the damped pathway I assumed the initial circumference suppression of the mine excavation U by 80% and the depression of the initial cross section area S by 90%. I interpreted the coefficient α from the tables of the underground ventilation $\alpha = 350\ kg\ .\ m^{-3}$. Then for different size of the initial profile the resistances appear in the range of

$R_{1m} = 500$ to $8\ 000\ kg\ .\ m^{-7}$ (pathways resistance per 1 metre in the damped mine excavation according to the degree of damping).

Further the method of determining resistance along the damped galleries consisted in verification of the computing models with a great file of measured values at degassing boreholes. I used in particular measurements at boreholes of the Hrusov Mine situated nearby the Ida shaft. [3].

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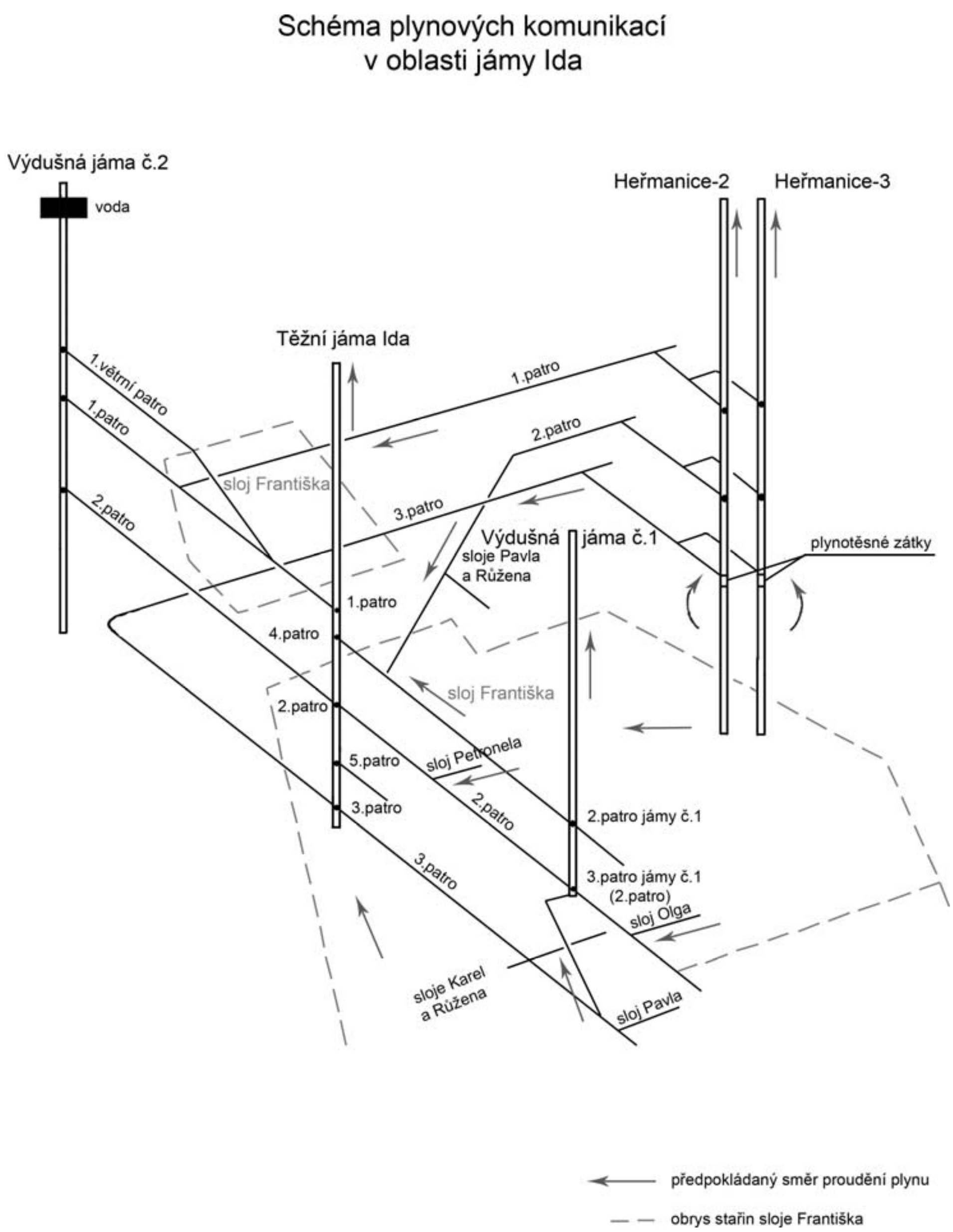

Obrázek č. 1 Schéma plynových komunikací v oblasti jámy Ida

Fig. 1 Gas communications scheme in Ida shaft area

Gas communications scheme in Ida shaft area

Discharge air shaft No.2 Hermanice-2 Hermanice-2

Water

Ida mine shaft

1st wind storey 1st storey

1st storey 2nd storey

Frantiska seam

2nd storey3rd storey

Discharge air shaft No.1 Gas-tight stopper

Pavla and Ruzena seams

1st storey

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4th storey

Frantiska seam

2nd storey

5th storey Petronela seam

3rd storey 2nd storey 2nd storey of shaft No.1

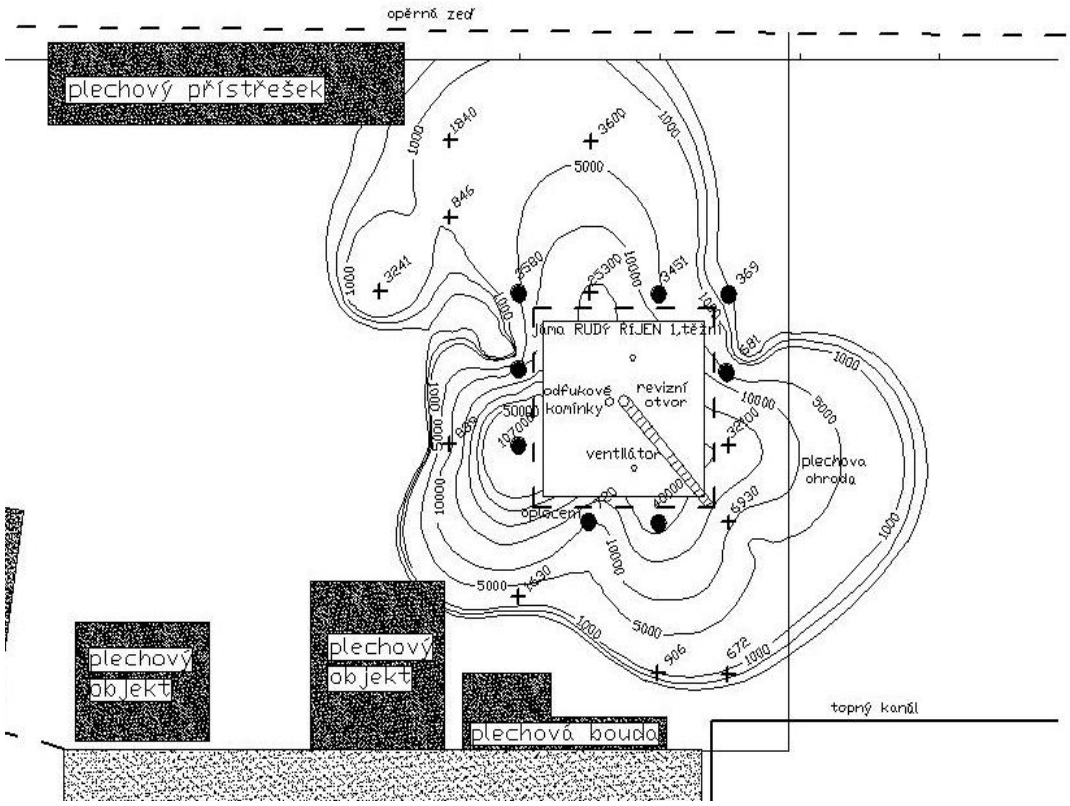
3rd storey 3rd storey of shaft No.1

(2nd storey)

Olga seam

Karel and Ruzena seams Pavla seam

- supposed direction of gas flow
- outline of abandoned working of Frantiska seam



Obrázek č. 2 Průzkum metanu v půdním vzduchu v okolí sanované jámy RUDÝ ŘÍJEN 1, těžní, (IDA 1, těžní)

Fig. 2 Methane survey in soil air round redevoleped RUDY RIJEN 1 shaft area, mining shaft (IDA 1)

Note: It results from Fig. 2 that in the area of atmogeochemistry probe 107000 a 40000 concentration of CH_4 5%-10% was measured. The mentioned units of concentration of CH_4 in Fig. 2 are in ppm.

Supporting wall

Sheet metal shelter

RUDÝ ŘÍJEN 1 shaft, mining

Lums Inspection hole

Ventilator

Sheet metal object Sheet metal object Sheet metal shed Heating flue

2.1 Drop of residual coal gas capacity in the surrounding of the Ida Shaft during a longer period of time.

In Fig. 2 there is given the state of methane concentration in the surrounding of the Ida mineshaft on 26th November 1998. According to the measurement that was performed in this area on 16th February 2005 upon the barometric pressure 1007 hPa zero concentration was found out. It follows from this that on certain conditions, i.e. the amount of the residual coal gas capacity and the volume of the area, from which the gas is produced a gradual drop of gas emission from the underground occurs.

3 MODELLING OF SITUATION OF GAS EMISSION NEARBY THE IDA SHAFT.

According to the stated input data, 3 variant calculations were processed to model the situation of gas leakage nearby the Ida shaft.

3.1 Real situation of gas emission from abandoned underground. Model variant 1.

The model of this variant is given in Fig. 3.

As it is obvious from Fig. 3, the exposed Ida shaft is depicted using nodes 1-2-3-4-5. In its vicinity it emits to the environment from the area of a tectonic disturbance (see projection in Fig. 1, Frantiska seam) gas (residual coal gas capacity) of the volumetric flow rate of 0,178 $m^3.s^{-1}$. I derived the value according to [2].

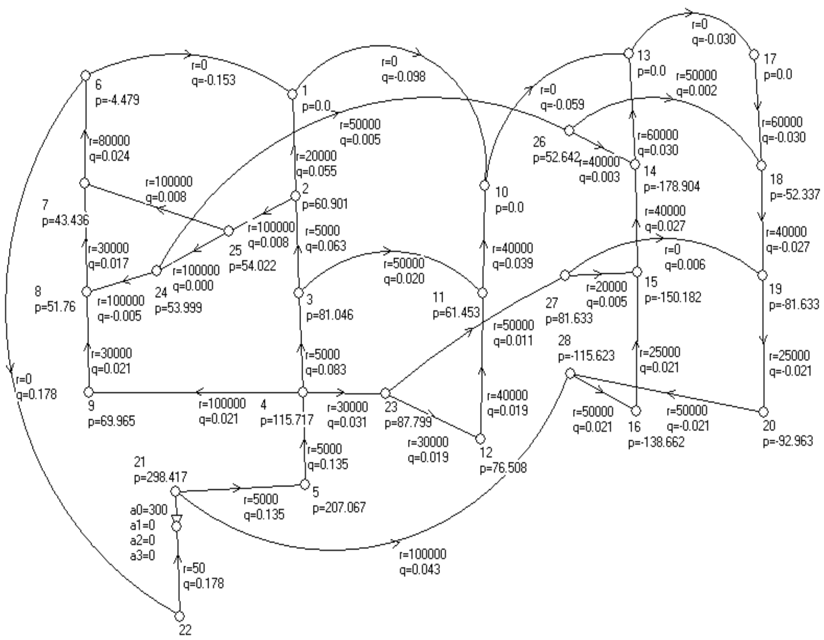
Gas distribution in the damped initial skeleton of galleries will cause that in the closed Ida shaft the mine atmosphere flows to the surface in the amount of 0.055 0,055 $m^3.s^{-1}$. At the same time in this shaft drop in pressure occurs in the node 5, p=207,0 Pa. The mine atmosphere under relatively high pressure found a way in the disrupted surroundings of the shaft (in soil) and caused the known problems.

As regards the value of the residual gas capacity, it can be considered as rather higher than found out in other localities of abandoned mines. There it did not exceed the value 0.15 $m^3.s^{-1}$.

There are indeed also exceptional cases, when for instance at the French Peyerimhoff mine in the Lorraine coalfield it reached 0,428 up to 0,671 $m^3.s^{-1}$. [4].

At the abandoned Paskov plant of the Paskov Mine it reaches the value of 0.243 $m^3.s^{-1}$.

The monitored values of the volumetric flow rate and pressure at next abandoned shafts are mentioned in tables 1 to 5.



Obrázek č. 3 Výpočet plynových komunikací v oblasti jámy Ida. (bez odplyňovacího vrtu).

Fig. 3 Calculation of gas communication in Ida shaft area (out of degassing borehole).

Risk of gas emission at the Ida shaft resulted in making decision by responsible organizations to establish in its neighbourhood a methane drainage borehole. The presumption was that the dangerous mine atmosphere would be drained this way with free escape to the air. The borehole MV 29 has been made around the shaft. If it was not flooded by water, it would obviously drain the gas. In the other variant I performed the calculation of this situation.

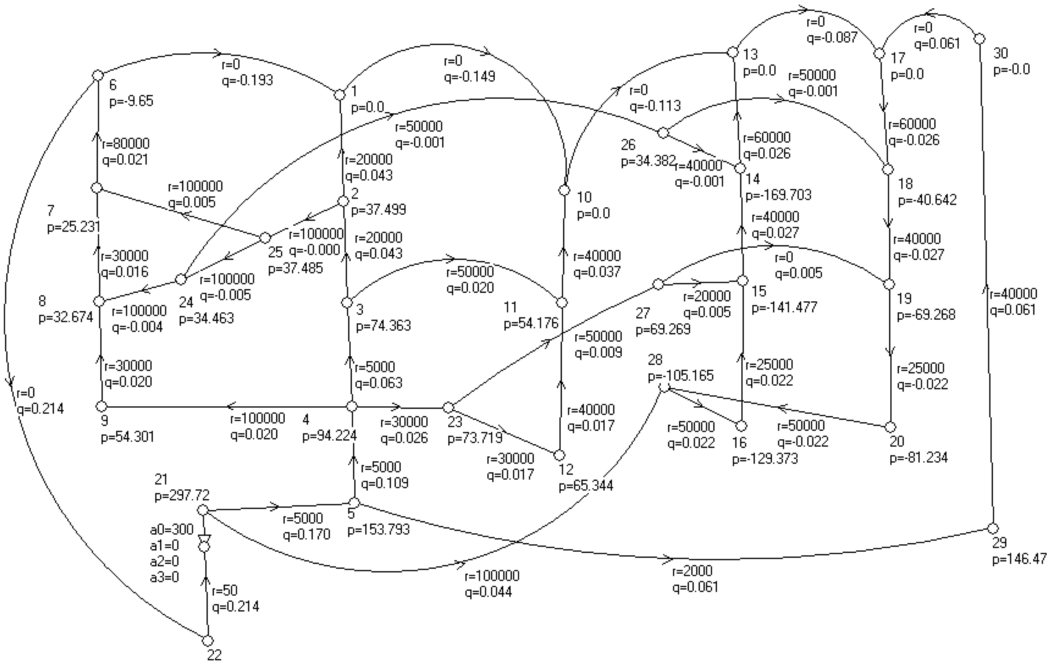
3.2 Situation with degassing borehole nearby the Ida shaft. Model variant 2.

The calculation for this variant is given in Fig. 4.

At present in the Ostrava-Karvina Coalfield the most widespread way of population protection is based on the system of methane drainage boreholes. Most often their diameter is ∅ 100 mm and resistance per 1 borehole R=r (in GrafSit) r_{1m}=800 kg.m^{-7} (the GrafSit program depicts the resistance of pathway with small letter „r“). See for instance [3].

It would be more advisable for situation at the Ida shaft to select a borehole with a larger diameter (with smaller r_{1m}).

From the model in Fig. 4, it is obvious that if the methane drainage borehole (nodes 29-30) is managed to be established so that between it and the exposed shaft a pathway was (nodes 5-29) with a relatively small resistance, r=2000 kg.m^{-7}, pressure values and volumetric flow rates at all shafts will drop. The degassing borehole will take away the mine atmosphere to the air. (Strictly said, gas should be drained and suitably used according to its concentration). However, by its establishment and its actual layout the risk of methane concentration in the built-up area has decreased.



Obrázek č. 4 Výpočet plynových komunikací v oblasti jámy Ida. (s odplyňovacím vrtem).

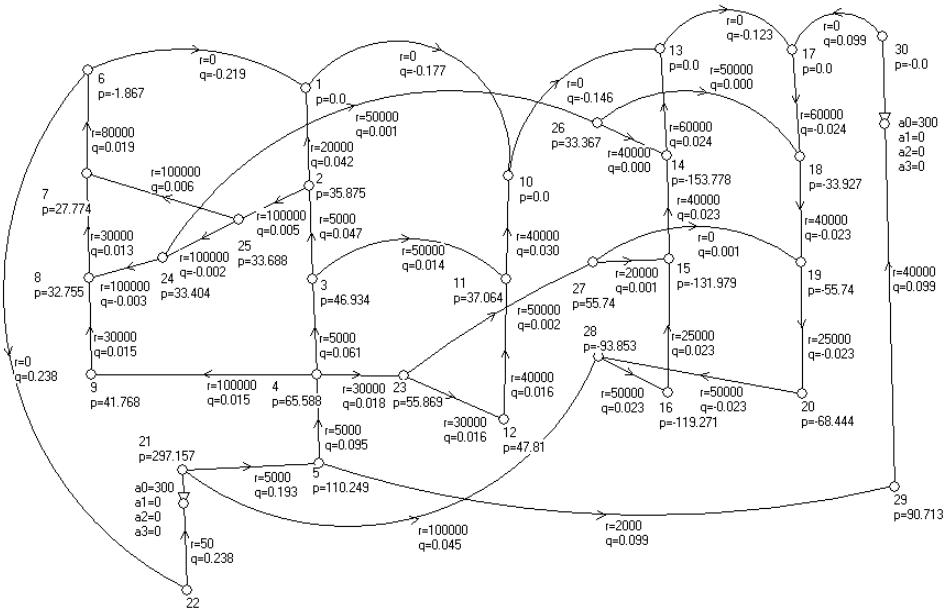
Fig. 4 Calculation of gas communication in Ida shaft area (with degassing borehole)

To increase efficiency of the degassing borehole it is advisable to implement there a suction system. This possibility I assessed in the variant 3.

3.3 Situation with degassing borehole nearby Ida shaft and suction system. Model variant 3.

The calculation for this variant is given in Fig. 5.

From the model in Fig. 5, it is obvious that if the degassing borehole (nodes 29-30) is managed to be established so that between it and the exposed shaft a pathway was (nodes 5-29) with a relatively small resistance, r=2000 kg.m^{-7} and a suction system is implemented there (in the modelled example with depression 300 Pa), the pressure values and volumetric flow rates at all shafts will drop very dramatically.



Obrázek č. 5 Výpočet plynových komunikací v oblasti jámy Ida. (s odplyňovacím vrtem, na kterém je umělé odsávání).

Fig. 5 Calculation of gas communication in Ida shaft area (with degassing borehole with suction system)

The overview of changed pressures and volumetric flow rates at the monitored objects in individual variants is given in tables 1 to 5.

Tabulka č. 1 Sledované hodnoty na jámě Ida

Tab. 1 The following indicates values at the Ida shaft

Ida Shaft (nodes 1-2-3-4-5)					
Without degassing borehole		Degassing borehole (nodes 29-30)		Degassing borehole with suction	
Volumetric flow rate (m^3/s)	Pressure in node 5 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 5 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 5 (Pa)
0,055	207,0	0,043	153,7	0,042	110,2

Tabulka č. 2 Sledované hodnoty na výdušné jámě č. 2

Tab. 2 The following indicates values at the discharge air shaft No. 2

Discharge air shaft No. 2 (nodes 6-7-8-9)					
Without degassing borehole		Degassing borehole (nodes 29-30)		Degassing borehole with suction	
Volumetric flow rate (m^3/s)	Pressure in node 9 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 9 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 9 (Pa)
0,024	69,9	0,021	54,3	0,019	41,7

Tabulka č. 3 Sledované hodnoty na výdušné jámě č. 1

Tab. 3 The following indicates values at the Ida discharge air shaft No. 1

Discharge air shaft No. 1 (nodes 10-11-12)					
Without degassing borehole		Degassing borehole (nodes 29-30)		Degassing borehole with suction	
Volumetric flow rate (m^3/s)	Pressure in node 12 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 12 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 12 (Pa)
0,039	76,5	0,037	65,3	0,030	47,8

Tabulka č. 4 Sledované hodnoty na jámě Heřmanice 2.

Tab. 4 The following indicates values at the Hermanice shaft No. 2

Hermanice shaft No. 2 (nodes 13-14-15-16)-					
Without degassing borehole		Degassing borehole (nodes 29-30)		Degassing borehole with suction	
Volumetric flow rate (m^3/s)	Pressure in node 16 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 16 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 16 (Pa)
0,030	-138,6	0,026	-129,3	0,024	-119,2

Tabulka č. 5 Sledované hodnoty na jámě Heřmanice 3.

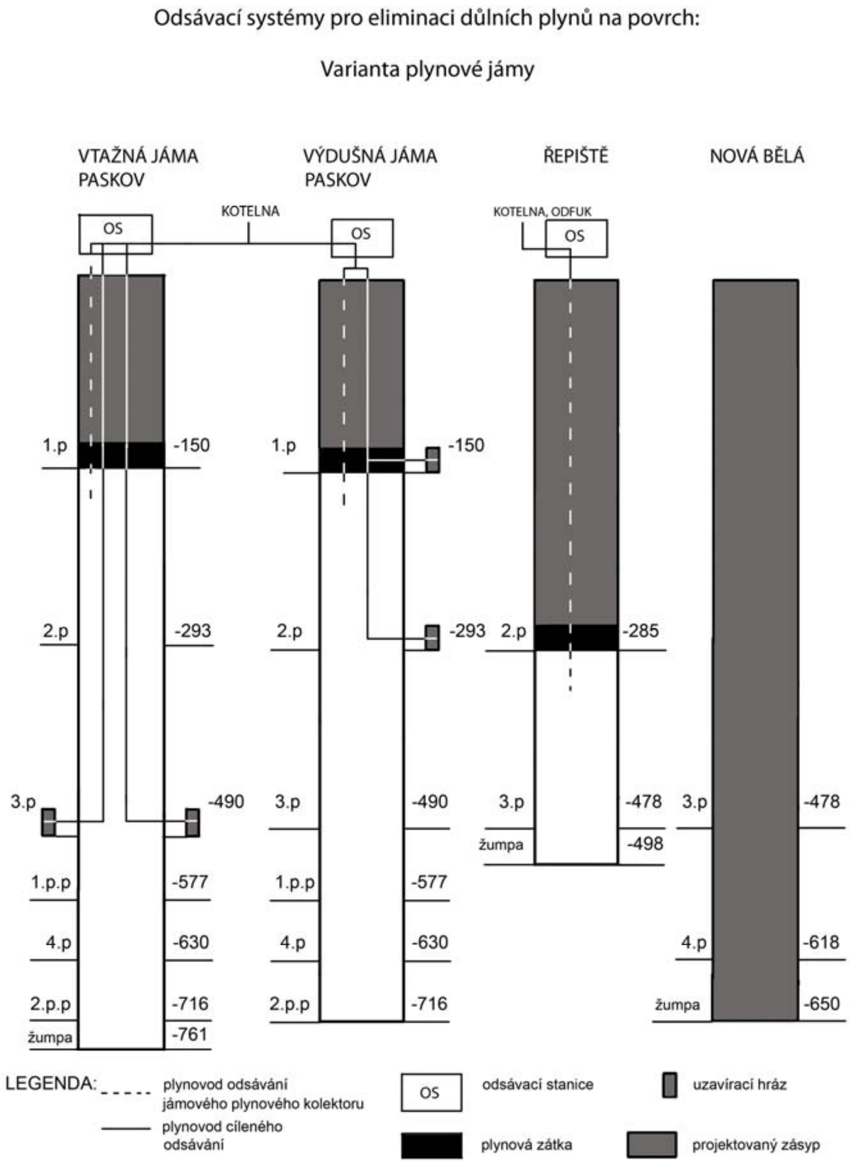
Tab. 5 The following indicates values at the Hermanice shaft No. 3

Hermanice shaft No. 3 (nodes 17-18-19-20)-					
Without degassing borehole		Degassing borehole (nodes 29-30)		Degassing borehole with suction	
Volumetric flow rate (m^3/s)	Pressure in node 20 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 20 (Pa)	Volumetric flow rate (m^3/s)	Pressure in node 20 (Pa)
0,030	-92,9	0,026	-81,2	0,024	-68,4

It results from the tables 1 to 5 that the equipment of the degassing borehole and at the next stage implementation of a suction system can significantly impair values of the pressure and volumetric flow rate at the exposed Ida shaft.

4 PROPOSAL OF POSSIBLE ENCLOSURE OF UNDERGROUND

It results from this paper that the way of closing the underground so that it was applied in case of the Ida shaft caused undesirable escapes of mine gases to the surface. The way depicted in Fig. 6 appears more convenient. It can be derived from that upon closing the shafts of the Paskov plant of the Paskov Mine (formerly Staric plant) a possibility to drain the mine gas by the degassing system was kept at the shafts that were closed. From experience with the method of enclosure it is possible to demonstrate that in the neighbourhood of the shafts being closed any mine gas leakage to the surface does not occur and on the contrary the supply of the gas is utilized for industrial purposes as a valuable economical source. Furthermore, it is presented as an applicable ecologic method of disposal of greenhouse gases.



Obrázek č. 6 Odsávací systémy pro eliminaci důlních plynů na povrch

Fig. 6 Suction systems of mining gases elimination on surface

Suction systems of mining gases elimination on surface

Gas shaft variant

PASKOV PASKOV REPISTE NOVA BELA

INTAKE SHAFT DISCHARGE AIR SHAFT

BOILER PLANT BOILER PLANT, GAS BLOW OFF

LEGEND: suction gas line pipe suction station bulkhead

of shaft gas collector

gas line pipe

of purposeful suction gas stopper planned backfill

5 CONCLUSION

The calculation according to the GrafSit model is one of the series of programs using which we try to assess theoretically gas communications in the closed environment of deep mines. As whatever program it has its advantages and restrictions. Using it we can model gas flow in a suppressed skeleton of an initial gallery network to a certain extent of reliability. Occurrence of such state is confirmed by measurements performed at a great number of degassing or other boreholes that were established consequently in exposed localities to protect the atmosphere.

A suppressed gallery network offers mostly a lower resistance than for instance an affected rock stratum. Therefore GrafSit can be applied also in such situation that is a substantial subject of this paper.

Of course, if it is necessary to express the way of gas penetration from the shaft Ida to surroundings especially of a surface built-up area across a rock stratum (soil), then another program would have to be used, for instance Fluent. As well to make further decisions, for instance to assess dynamics of development in the closed underground, more suitable models would have to be found.

However, for situation being the subject of this solution the GrafSit application showed its eligibility. It is possible to draw the following undoubted conclusions from the given models:

- In case of a mine enclosure it is not suitable in principle to close simultaneously all connections with the surface (shafts and similar mine excavations), as it is mostly done so far.
- It is necessary in advance to track the development of the residual coal gas capacity in single areas of the mine that shall be closed. This can differ in various parts of wind areas.
- According to the value of the residual coal gas capacity we can assess based on the theoretical model, which of the mine excavations can be used to an organized seducement of the mine atmosphere. It should be then technically adapted for this possibility. See for instance the shaft of the Paskov plant of the Paskov Mine in OKR.
- In case of the shaft Ida it need not be necessary to establish any degassing borehole and its function could be take over by the very shaft after the adaptation.

From this point of view the use of the computing program and its application to a particular situation is significant.

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RESUMÉ

Výpočet podle modelu GrafSit je jedním z řady programů, kterými se pokoušíme teoreticky posoudit plynové komunikace v uzavřeném prostředí hlubinných dolů. Jako každý program má své výhody i svá omezení. Dá se jím s jistou mírou spolehlivosti modelovat proudění plynu v potlačené kostře původní větrní sítě. Že v ní skutečně k takovému stavu dochází potvrzují měření na velkém počtu odplyňovacích a jiných vrtů, které byly v exponovaných lokalitách následně zřízeny k ochraně atmosféry.

Potlačená větrní síť klade prostupu plynu převážně menší odpor, než například ovlivněná horninová vrstva. Proto se GrafSit může uplatnit i v situaci, která je podstatnou náplní tohoto příspěvku.

Pokud by ovšem bylo zapotřebí vyjádřit, jak pronikal plyn z jámy Ida do okolí, zejména povrchové zástavby přes horninovou vrstvu (půdu), pak by musel být požit jiný program. Například Fluent. Ale i k řadě dalších rozhodnutí, například posouzení dynamiky vývoje v uzavřeném podzemí, by se musely hledat vhodnější modely.

Nicméně pro situaci, která je předmětem tohoto řešení, prokázala zde uvedená aplikace programu GrafSit své oprávnění. Z uvedených modelů lze vyvodit tyto nepochybné závěry:

- V případě uzavírání dolů není zásadně vhodné uzavřít současně všechny spoje s povrchem (jámy a obdobná díla), jak se to dosud převážně praktikuje.
- Je nutno v předstihu sledovat vývoj zbytkové plynodajnosti v jednotlivých oblastech dolu, který má být uzavřen. Ta může být v různých částech větrních oblastí různá.
- Podle hodnoty zbytkové plynodajnosti teoretickým modelem posoudit, které z děl může být využito k organizovanému svádění důlní atmosféry. To by pak mělo být technicky upraveno na tuto možnost. Viz například jáma závodu Paskov, Dolu Paskov v OKR.
- V případě jámy Ida by mohla odpadnout potřeba zřizovat odplyňovací vrt a jeho funkci by po úpravě převzala vlastní jáma.

Z tohoto hlediska je uplatnění výpočetního programu a jeho aplikace na konkrétní situaci významné.