POSSIBILITIES OF UTILIZATION OF GAS RESERVES IN ABANDONED UNDERGROUND AS ENERGY RESOURCES

MOŽNOSTI VYUŽITÍ ZÁSOB PLYNU V UZAVŘENÉM PODZEMÍ JAKO ZDROJE ENERGIE

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Abstract

New problems revealed after finishing outputs in the coal mines in the Czech Republic and in another countries, too. The economic situation at the end of the last century led to an intense restriction of mining and the mines were closed. In many cases, as well in Ostrava-Karvina basin also the mine ventilation and degasification were interrupted. During the closing of the mines, especially the shafts and mine workings connected underground areas with the surface, laws of gas distribution were not respected often enough. It resulted in the known problems of gas emissions to the surface. The closed underground thus represents a gas reservoir where the gas is not only gathered, but also produced. So there is a possibility to use the gas as a potential power resource.

Abstrakt

Po ukončení těžby v České republice, ale i dalších zemích, se objevily nové problémy. Ekonomická situace ke konci dvacátého století způsobila restrikci dobývání a uzavření dolů. V řadě případů, jakož i v ostravsko-karvinském revíru, byla ukončena degazace a větrání. Během uzavírání dolů, zejména jam a děl spojujících podzemí s povrchem, nebyly často respektovány zákony distribuce plynů. To způsobilo známý problém výstupu plynů z podzemí na povrch. Uzavřené podzemí tak představuje zásobník plynu, v němž se plyn nejen shromažďuje, ale i produkuje. Tak se nabízí možnost, získat tento plyn jako potenciální zdroj energie.

Key words: mine ventilation, gas, methane, energy supply

1 INTRODUCTION

New problems revealed after reducing outputs in a number of coalfields in the world and in the Czech Republic, too. It must be said that economic development at the end of the last century led to an unusually high rate of reducing of coal mining and closing of mine areas. In many cases, and it pertains to the Ostrava-Karvina Coalfield (OKR), too, whose problems I intend to assess, the degasification and ventilation were interrupted. It was followed by closing shafts and workings connecting the underground with the surface. However, not always regularities of gas distribution were respected in the new situation. The known problems of uncontrolled gas emissions especially methane to the surface occurred.

On the other hand, the closed underground represents also a gas storage, for the gas continues to be produced and so a possibility arises to utilize its natural energy.

2 APPROACH TO SOLVING THE ISSUE

As regards the gas energy, in our case of methane, [5] shows interesting data on dependence of calorific value in air-methane mixture on CH_4 concentrations (see Fig. 1).

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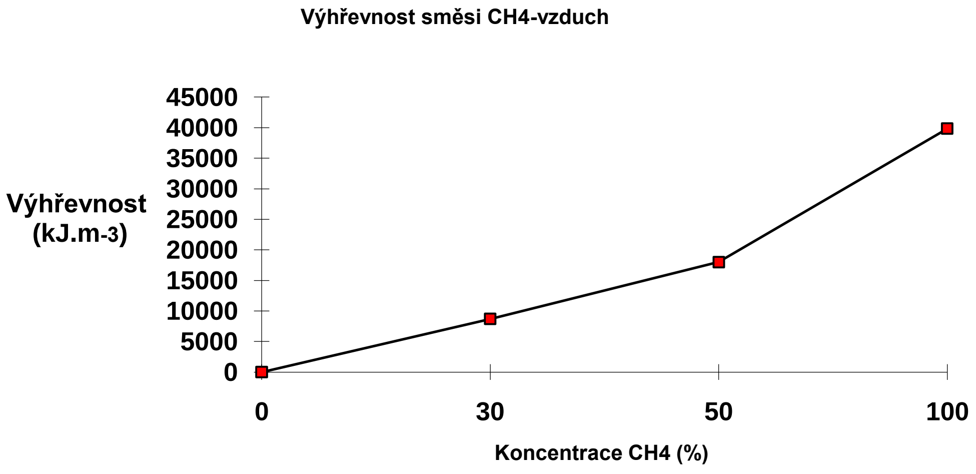

CH4-air mixture caloric value
Caloric value (kJ.m-2)
CH4 concentrations (%)

Fig. 1 Calorific value of air-methane mixture in dependence on CH_4 concentrations.

Also in OKR we have some data available which can provide an idea on a possibility of a specific utilization. In order to handle the dangerous gas emissions from underground areas responsible organizations especially OKD DPB a.s. have made a major number of methane drainage boreholes. At some of them exhaust tests were performed to verify the gas reserve and its possible utilization for economic reasons.

There were realized several of them in OKR. I mention here results from Hrusov Mine (HD1 borehole) and from the area of Petrkovice (MV40 borehole).

However, it is necessary first to say that such exhaust test is a costly matter. The costs of the test per 1 day are about CZK 45,000. Therefore the test is performed to an limited extend and in the most essential cases.

In the locality of Hrusov Mine the exhaust test was performed during the period from 21st to 23rd September 2000 at the HD1 borehole with the following result. For the duration of the test, i.e. 38 hours, an average quantity of gas mixture of $9{,}8 \cdot 10^{-2}\ m^3 \cdot s^{-1}$ was exhausted.

The total volume of the exhausted mixture was 3 452 m^3. CH_4 concentration during that time decreased from 43 % to 24,5 %.

According to this trend it can be presumed that in further 38 hours the methane content would decrease to a value near zero. It would indicate that the volume of free gaps could be in this case ca 26000 m^3. The expected energy utilization at 30% concentration of CH_4 would be then

$$P_{tep} = q \cdot Q_v \qquad [kW] \qquad (1)$$

Where: P_{tep} - heat output of gas [kW]

q - calorific value of CH_4 at a given concentration [kJ . m^{-3}]

Q_v - volume flow rate of the mixture [m^3 . s^{-1}]

After substitution:

$$P_{tep} = 8706 * 8{,}33.10^{-2} = 725kW$$

Considering the limit of exhaustion of the gas reserve the source does not prove yielding.

In the locality of Petrkovice at the MV40 borehole an exhaust test passes on 16th - 17th October 2002. The average exhausted quantity of the gas mixture was $7{,}5 \cdot 10^{-2}\ m^3 \cdot s^{-1}$.

Throughout the exhaustion, i.e. 24 hours, 6 480 m^3 of methane+other gases mixture was thus exhausted. However, the CH_4 concentration here did not decrease for the duration of the test and reached permanently 45 %.

Here a more significant effect could be reached.

From the localities that have already been closed in OKR the gas from Paskov Plant, Paskov Mine is utilized as a suitable energy source. Herefrom by means of the degassing system ca $12 \cdot 10^6$ of air-methane mixture with the CH_4 concentration of 70 % has been gathering and supplying to the energy supply network since its closing in the year 1994.

A great part of the successful solution consists in a suitable way of closing coal shafts and in keeping of the degassing station function. The method of closing shafts is presented in Fig. 2 [2].

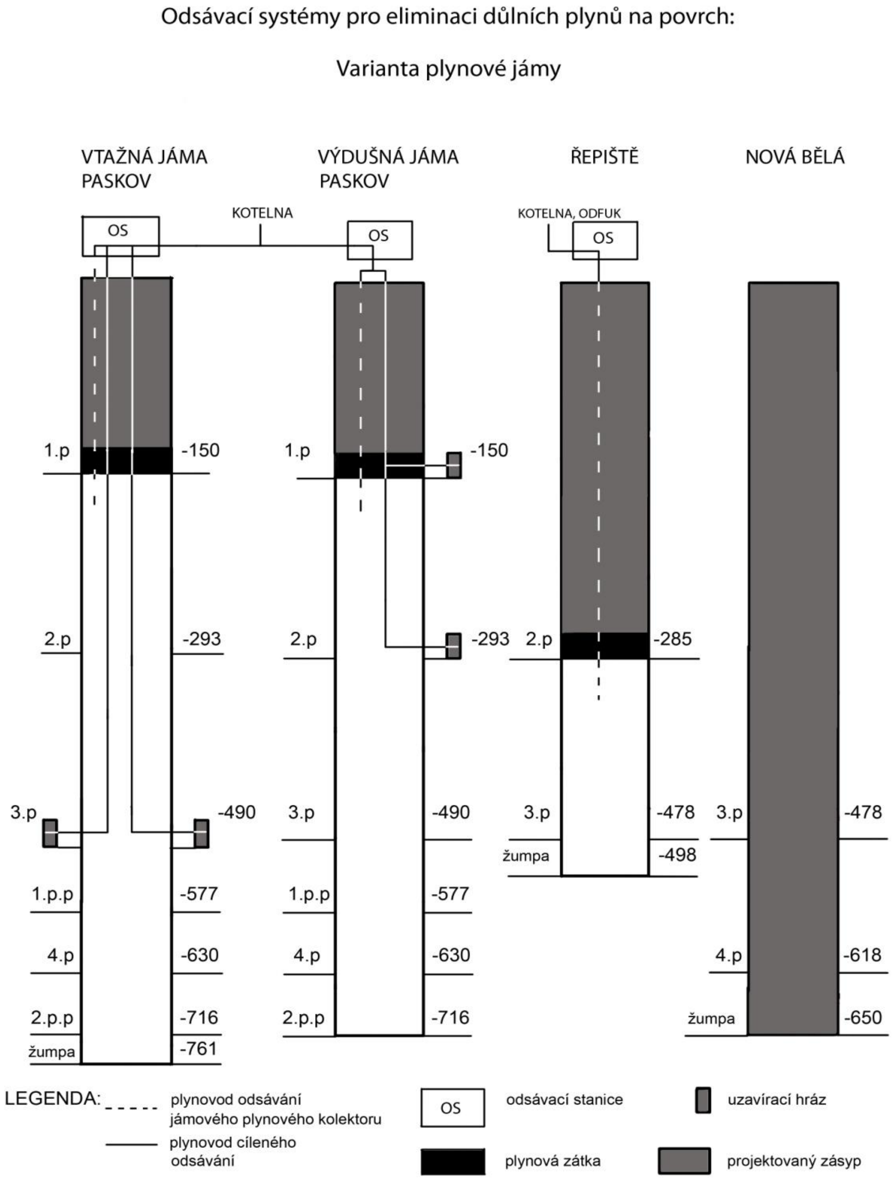

Fig. 2 Method of closing shafts of Paskov Plant[2]

Exhaust systems for elimination of emissions of mine gases to the surface

INTAKE SHAFT PASKOV   UPCAST SHAFT PASKOV   REPISTE   NOVA BELA

LEGEND:	exhaust pipeline of shaft gas collector	exhaust station	bulkhead
	pipeline of purposeful exhaustion	gas plug	projected backfill

As it is known this originally separate mine was open by four shafts. It results from Fig. 2 that after reducing of mining in three shafts the gas (degassing) pipeline intervening up to the shaft level of -490 m was preserved. But also at the shaft levels of -150 m and –293 m the gas pipeline is taken out behind gas plugs and so the gas drainage from considerably large gaps is enabled.

By then the case in OKR is unique, however just these findings should be used in further course of damping being expected in this locality.

It results from the comparison of the two presented examples of the gas exhaustion at Hrusov methane drainage borehole and the gas drainage by conveniently closed shafts from Paskov Plant that in order to gather a sufficient gas reserve as an energy source it is necessary to apply the system of Paskov Plant.

By then the possibility of utilization of alternative resources seems to get no needful support. To a great extent it relates to the relative economic effectiveness and setting price of electric energy in the public supply mains.

3 FINDINGS OF SOLVING THE ISSUE IN GERMANY

Abroad the issues of utilization of gas energy from closed underground areas is given an increased attention. I present an entire passage from [1] on intentions of gas utilization in North Rhine-Westphalia in Germany.

However, in actual reflections on mine gas as a source of danger and as a negative ecological factor a substantial aspect of mine gas remains neglected. Except for noxious effects of mine gas here also its positive property exists as a source/carrier of energy. Methane disposes of the power density of ca 5,9 $\mathrm{kWh \cdot l^{-1}}$ or 13,9 $\mathrm{kWh \cdot kg^{-1}}$. Therefore (with respect to the lack of sources of other fossil fuels) a needful pursuit of utilization of mine gas appears. Via the Renewable Energy Sources Act (EEG) in 2000 an economic impulse was created for wide energy utilization of mine gas. The Act imposes to operators of mains in Germany to undertake to purchase mine gas and replace current supply just from mine gas. Such replacement of power supply for plants represents 500 $\mathrm{kW_{el}}$ - 15 $\mathrm{Pf \cdot kWh_{el}^{-1}}$, for larger plants then 13 $\mathrm{Pf \cdot kWh_{el}^{-1}}$ at least. Under such conditions the mining and utilizing of mine gas have become profitable.

An example of a shaft modification for allowing methane drainage is illustrated in Fig. 3 according to [7].

From the figure it is obvious that the methane drainage pipeline is likewise as in the case of Paskov shaft drained behind gas plugs. Two images in Fig. 4 show the view of an exhaust plant at abandoned shafts in Germany.

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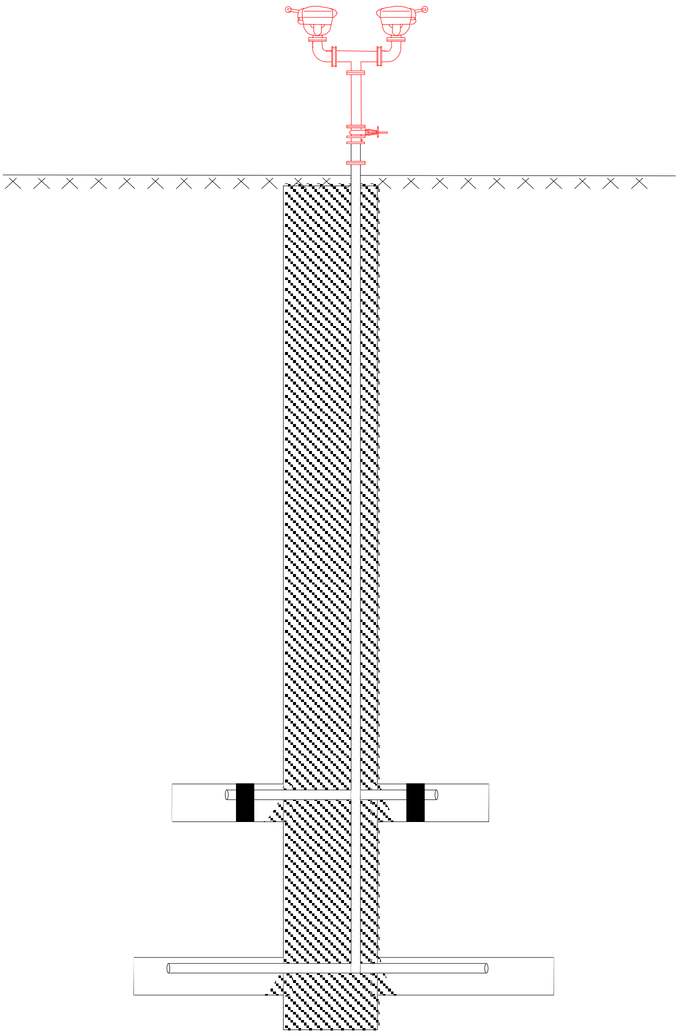


Fig. 3 Modification of gas pipeline in an abandoned shaft according to [1] from Germany

Fig. 4 Degassing plant at abandoned shafts in Germany [7]

4 DETERMINATION OF GAS RESERVES IN ABANDONED UNDERGROUND AREAS

In order to decide whether a project of methane drainage from abandoned underground areas is effective it is necessary to know gas underground reserves. In solving the task two following situations exist in principle:

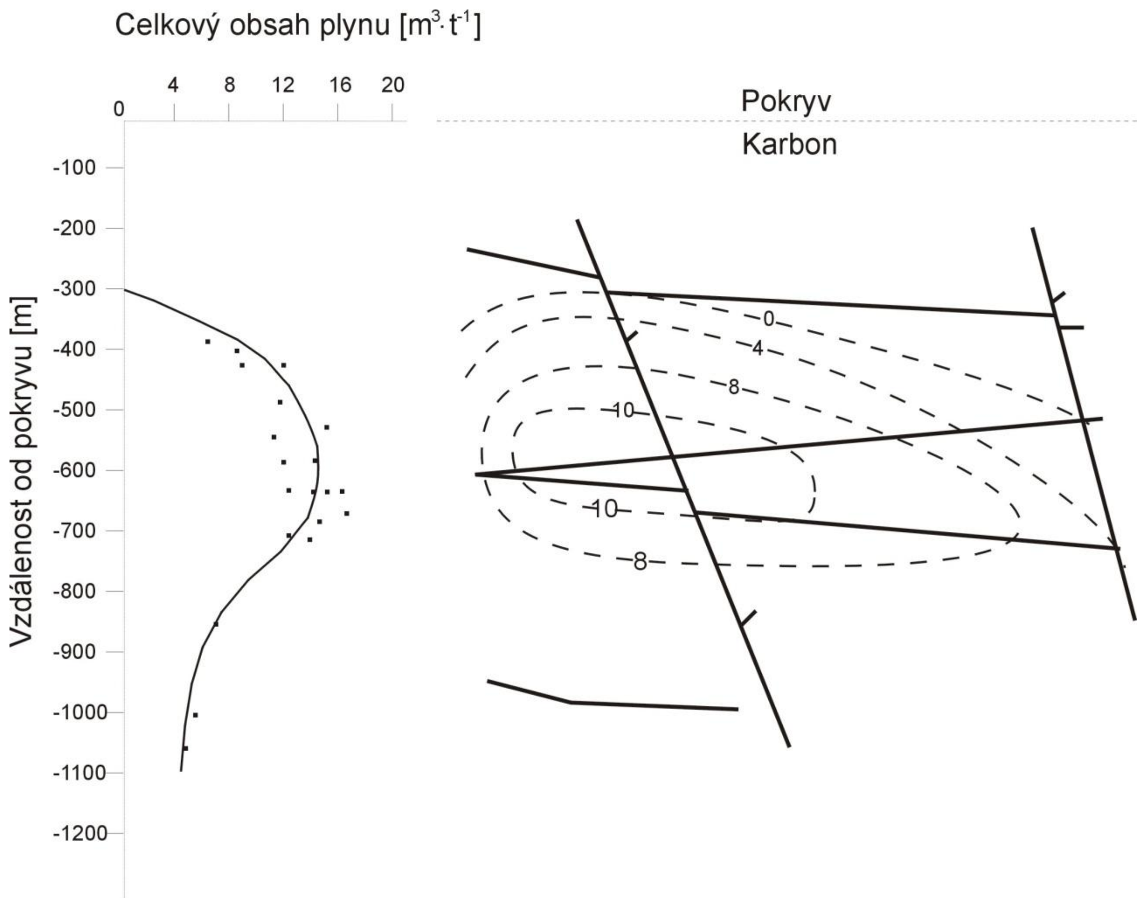
Prior to closing the underground areas needful details were not acquired according to which it would be possible to determine at least approximately the value of a residual gas capacity.

We close today still active mine and gather necessary details for determining the residual gas capacity and volumes of free gaps.

In situation where there were not found out needful values prior to closing the underground areas it is necessary to carry out an exhaust test or apply a computing model. For such exhaust test as well computing model as a rule methane drainage boreholes will serve. There have been performed a lot of them in OKR locality. By means of continuous measurements of volume flow rate, difference of pressures underground and on the surface and gas concentrations at those boreholes we obtain preliminary data on the situation in the abandoned environment. As actual works [2,3] as well results of exhaust testing shows there were not found out by then such methane sources that could lead to its industry utilization. However, it must be added that from the results at methane drainage boreholes whose depth does not usually exceed 50 m we can derive incomplete conclusions only. Provided that the borehole is deepened the deeper parts will certainly produce a greater quantity of gas with higher concentrations.

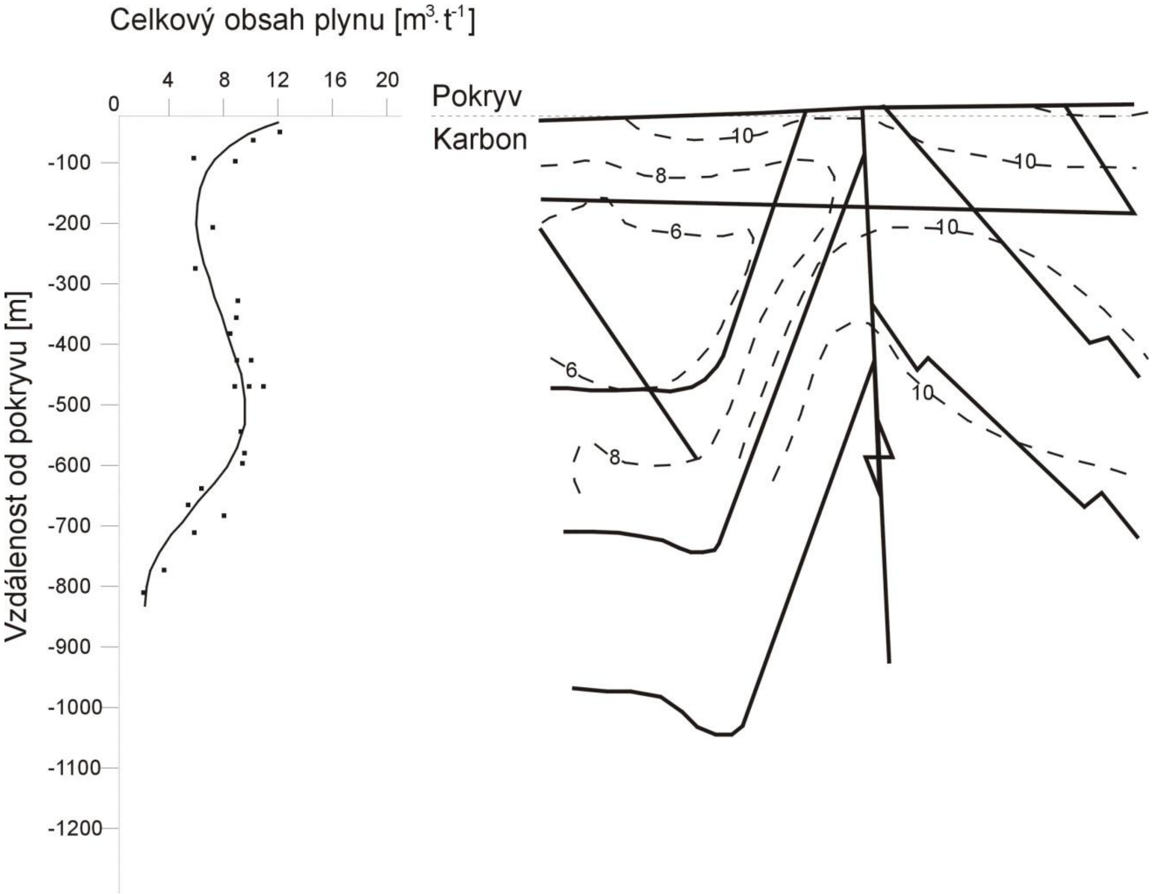
Certain proofs can be just the results from the mentioned Paskov Plant. The degassing pipeline taken out to a depth of -490 m drains on a long-term basis gas with emissions of 0,243 [m^3 $CH_4.s^{-1}$].

We have available certain data on division of gas reserves according to [7]. (See Fig. 5 and 6)



Overall gas content ($m^3.t^{-1}$)
Cover
Carbon
Distance from cover (m)

Fig. 5 Allotment of gas reserves in underground areas depending on the depth of seating and arrangement of seams in situation when the seam is at the level of -200 m



Overall gas contents ($m^3.t^{-1}$)
Cover
Carbon
Distance from cover (m)

Fig. 6 Allotment of gas reserves in underground areas depending on the depth of seating and arrangement of seams in situation when the seams are in close proximity under the cover

It results from Figs. 5 and 6 that for different storage of seams the distribution of gas reserves in abandoned underground areas is different. In the Czech Republic survey works for verification of the fact have not been performed so far to a wider extent. And just a more detailed study of these regularities could bring a significant progress of our knowledge of possible utilization of gas from deeper parts of mines. In the work [7] there is also presented that the residual methane volume amounts to 1,35 m^3*t^{-1} f of ribside. Also this can serve to more reliable estimation of actual gas reserves.

While closing today still active mines it is possible to use for determining a residual gas capacity and volumes of free gaps the procedure that was derived in [6]. According to the results of air and gas balance, which is a routine matter in controlling safety, a value of the residual gas capacity can be found out as one of meaningful factors which affects gas emissions from underground areas of abandoned mines and predicates of a real gas reserve underground.

As an example of the method called "method express" I present its application at Paskov Plant.

In tables 1, 2 and 3 there are shown values of methane concentrations, volume flow rates of winds and calculated emissions of all closed coal faces and long mine workings, followed by methane exhalations drained by all upcast mine shafts and degassed quantity of methane.

Results of complex gas balance of Paskov Mine

Tab. 1 Methane exhalations from faces

Face number	CH_4 concentrations		Volume flow rate of winds Q [m^3 . s^{-1}]	CH_4 exhalation Pd_5 [m^3 CH_4.s^{-1}]
	Intake c_1	Discharge c_2		
200 203	0	0,1	6,15	0,00615
200 308	0	0,2	5,83	0,01167
201 507	0	0,3	9,67	0,029
400 207	0	0,1	5,62	0,00562
420 100	0	0,2	8,33	0,01667
420 207	0	0,2	8,33	0,01667
421 411	0	0,5	9,17	0,04583
601 403	0	0,4	9,9	0,0396
$\sum Pd_5$				0,17121

Tab. 2 Methane exhalations from long mine workings

Face number	CH_4 concentrations		Volume flow rate of winds Q [m^3 . s^{-1}]	CH_4 exhalation Pd_5 [m^3 CH_4.s^{-1}]
	Intake c_1	Discharge c_2		
200 225/1	0	0,1	5,83	0,00583
203 660	0	0	4,67	-
203 660/1	0	0,1	4,67	0,00467
201 576	0,1	0,5	6,17	0,02468
400 321	0,1	0,5	5,17	0,02067
400 376	0	0,1	6	0,006
401 566	0,1	0,6	5,83	0,02915
404 520	0,1	0,3	4,17	0,00833
420 362	0,1	0,4	5,83	0,01749
420 163	0,1	0,5	6,17	0,02468
420 165	0	0	6	-
420 151	0	0,2	5,83	0,01167
420 360	0,1	0,6	6,17	0,03085
421 122	0,1	0,7	6	0,036
421 681	0	0	6,17	-
421 573	0,1	0,4	6	0,018
460 221	0	0	4,83	-
460 265	0	0	5,83	-
581 460	0	0	6,42	-
661 461/1	0,1	0,5	6,25	0,025
661 466	0,2	0,8	4,41	0,02646
661 469	0,1	0,7	6,17	0,03702
421 160	0	0,5	6	0,03
421 575	0	0,1	6	0,006
$\sum Pd_6$				0,3625

Tab. 3 Methane exhalation drained by upcast shafts of mine

Upcast shaft	CH_4 exhalation E_2 [m^3 $CH_4.s^{-1}$]
1	0,4267939
2	0,3659953
$\sum E_2$	0,7927892

Quantity of the degassed pure methane $Pd_4 = 0{,}3111111$ [m^3 $CH_4.s^{-1}$].

To calculate the residual gas capacity Pd_0 the relation (2) is used that was derived in [6].

$$Pd_0 = \sum_1^m E_2 + Pd_4 - \sum_0^k Pd_5 - \sum_0^h Pd_6 \qquad [m^3\ CH_4.s^{-1}] \qquad (2)$$

Where: Pd_0 - residual gas capacity [m^3 $CH_4.s^{-1}$]

E_2 - methane exhalation drained by all upcast shafts [m^3 $CH_4.s^{-1}$]

Pd_4- quantity of pure methane drained by the degassing station from the entire mine [m^3 $CH_4.s^{-1}$]

Pd_5 - actual gas capacity of operated faces [m^3 $CH_4.s^{-1}$]

Pd_6 - actual gas capacity of operated workings [m^3 $CH_4.s^{-1}$]

k - number of operated faces at the time of measurements [-]

h - number of operated long workings at the time of measurements [-]

m - number of upcast shafts [-]

After closing the mine (all shafts were filled and sealed), in short time period (of 3 months) methane production in the degassing system was interrupted. Pd_4 value practically dropped to zero. So the factual solution of the equation (2) for the situation after closing mine is as follows:

$$Pd_0 = 0{,}7928 - 0{,}1712 - 0{,}3625 = 0{,}2591 \ m^3 CH_4.s^{-1}$$

By measurements that pass at the control exhaust pipeline located to this purpose in one of the filled shafts a value of the residual gas capacity in the period of low barometric pressure is being found out as follows:

$$Pd_0 = 0{,}2435 \ [m^3\ CH_4.s^{-1}].$$

This comparison proves an acceptable reliability of the “method express”. At the same time it provides with sufficient details for making decision on the method of gas drainage and utilization of its energy potential in mines, where the procedures are available.

4 CONCLUSION

In the presented paper possibilities of utilization of gas reserves in abandoned underground areas as energy reserves are assessed. It results from the presented analysis that opportunities obviously exist how to use the indispensable potential. In mining operations, where mining was terminated and workings connecting the underground areas with the surface were closed the existing methane drainage boreholes may be used for the purpose. Provided that an exhaust test proves a presence of more yielding source it is real to use the gas potential by available means. For instance by gas blowing engines or degassing stations. I consider as highly significant the circumstance that the higher increase of seating depth is the more significant gas reserve can occur in abandoned mines. Therefore I recommend orienting in this direction research works to verify such areas.

In active mines where the reducing of mining is only expected it is recommended to use possibilities of air and gas balance to determine the residual gas capacity. By an adequate closing of shafts with keeping the degassing pipeline in larger depths to use then the emission as an energy resource.

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RESUMÉ

Uzavřené podzemí je zásobárnou plynu, protože ten se produkuje i nadále a nabízí se tak možnost využití jeho energetického potenciálu.

V uvedeném příspěvku se posuzují možnosti využít zásob plynu v uzavřeném podzemí, jako zdroje energie. Z předloženého rozboru vyplývá, že zřejmě existují příležitosti, jak tento nezanedbatelný potenciál využít. V důlních provozech, kde už byla těžba ukončena a důlní díla spojující podzemí s povrchem uzavřena, lze k tomu účelu využít stávající odplyňovací vrty. Pokud odsávací zkouška prokáže přítomnost vydatnějšího zdroje, je reálné využít potenciál plynu dostupnými prostředky. Například dmychadly, nebo degazačními stanicemi. Za důležité zjištění pokládám okolnost, že s růstem hloubky uložení, se může v uzavřených dolech vyskytnout významnější zásoba plynu.

Srovnáním dvou příkladů odsávání plynu na odplyňovacím vrtu Hrušovského dolu a svedení plynu vhodně uzavřenými jámami ze závodu Paskov vychází, že pro získání dostatečné zásoby plynu jako energetického zdroje je nutno aplikovat systém závodu Paskov. Zatím se ale zdá, že tato možnost využití alternativních zdrojů ještě nezískala potřebnou podporu. Do značné míry to souvisí s relativní ekonomickou efektivností a stanovení ceny elektrické energie v distribučních sítích.