UTILIZATION OF GAS FROM CLOSED UNDERGROUND COAL MINES

VYUŽITÍ PLYNU Z UZAVŘENÉHO PODZEMÍ UHELNÝCH DOLŮ

Petr URBAN

Ing. PhD., Institut hornického inženýrství a bezpečnosti, Hornicko-geologická fakulta, VŠB-TU Ostrava 17. listopadu 15,708 33 Ostrava-Poruba, tel:.(+420) 59 732 3357
e-mail :petr.urban@vsb.cz

Abstract

The paper deals with the possibility of using gas from closed underground coal mines in the Ostrava-Karvinna Coalfield in the Czech Republic (OKR). It proves that by suitable closing shafts it is possible to get through the use of technical equipment a relatively significant source of energy. It considers how to use for these reasons degassing boreholes.

Abstrakt

V příspěvku se uvádí možnosti získání plynu z uzavřeného podzemí dolů v Ostravsko-karvinském revíru (OKR). Dokazuje se, že při vhodném způsobu uzavření původních jam lze technickým zařízením získat poměrně významný zdroj energie. Posuzuje se možnost, jak pro obdobný účel využít odplyňovací vrty.

Key words: Gas, methane, closing mines, degassing boreholes, use of energy

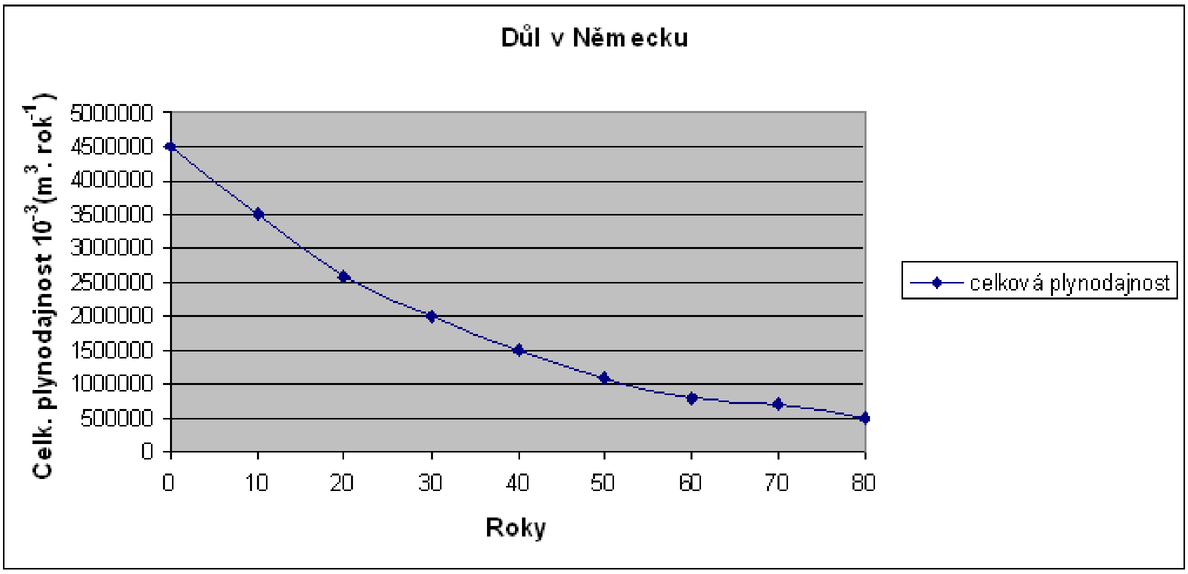
1 INTRODUCTION

In the last period due to increasing prices of oil and natural gas ways are explored to use alternative energy sources. There is a possibility to get gas, mainly methane, from abandoned underground coal mines. This paper considers the results achieved in this area so far, especially the experience gained in the OKR by the organization Green Gas DPB, a.s. These findings are compared with some similar examples from Germany.

At the same time, the paper also evaluates, which parameters should be monitored during the realization of that project. If the method for sucking off gas and its use as a heat source, or to produce electricity is implemented at a mine with a low gas reserve, it could be a wasted investment.

2 GAS RESERVES IN ABANDONED UNDERGROUND AREAS

According to data in [1] the development of gas reserves runs according to certain regularities. During the period of production (active mine) its development declines. After completing coal mining and closing the mine a portion of natural desorption reveal itself, which has a different course. It is clearly documented in Figure 1 and by the shown values of residual gas capacity.



Mine in Germany
Total gas capacity 10^{-3} ($m^3.year^{-1}$)
Years
Total gas capacity

Fig. 1 Development of total gas capacity at a typical mine in Germany, according to [1].

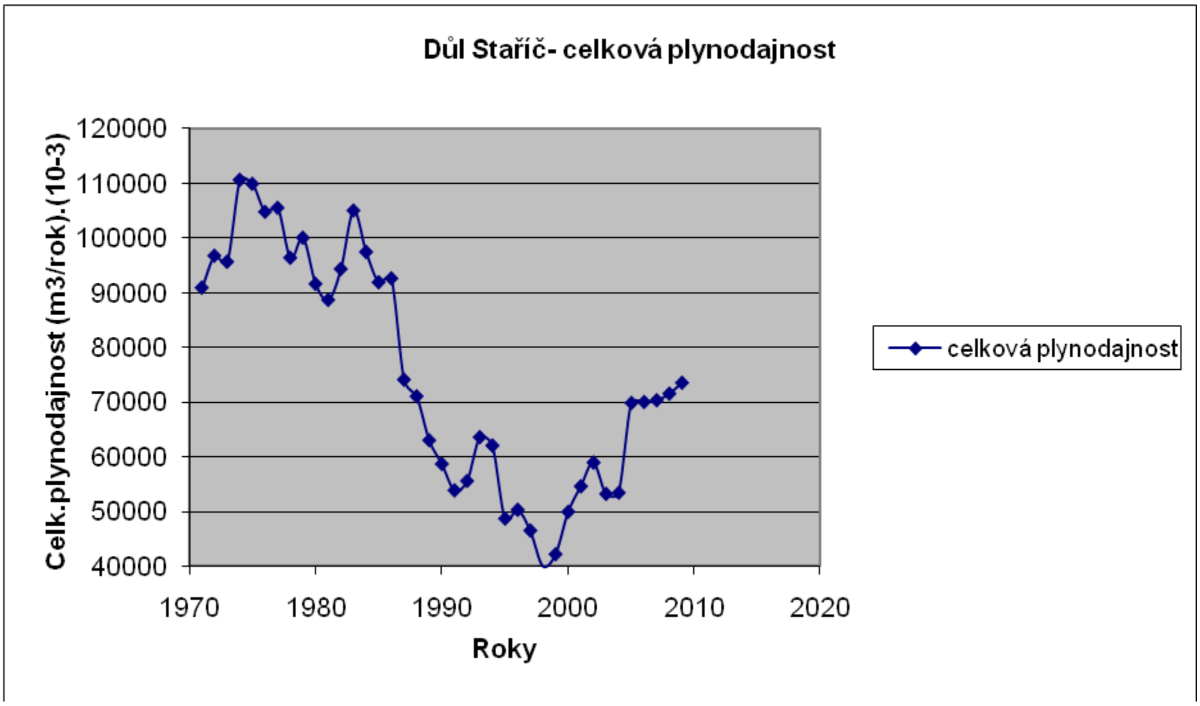
Regarding the residual gas capacity, [1] provided a modest figure only. Upon completion of extraction the remaining gas capacity was 650.10^6 $m^3.year^{-1}$ and within 10 years it fell to 491.10^6 $m^3.year^{-1}$.

Desorption after completing the extraction is indicated in the same source in the value of 1800 $m3.h^{-1}$, i.e. 0.5 $m^3.s^{-1}$.

Note: To maintain the same unit indications of total and residual gas capacities as they are shown in the relevant statements of mining companies, the values of total and residual gas capacities (m3.year-1) in the graph in Figure 1 and Figures 2, 3, 4 are 1000 times lower than in reality. This means that upon commencement of mining operations at the mine according to Figure 1, the annual production of methane was $4,5.10^9$ m^3.

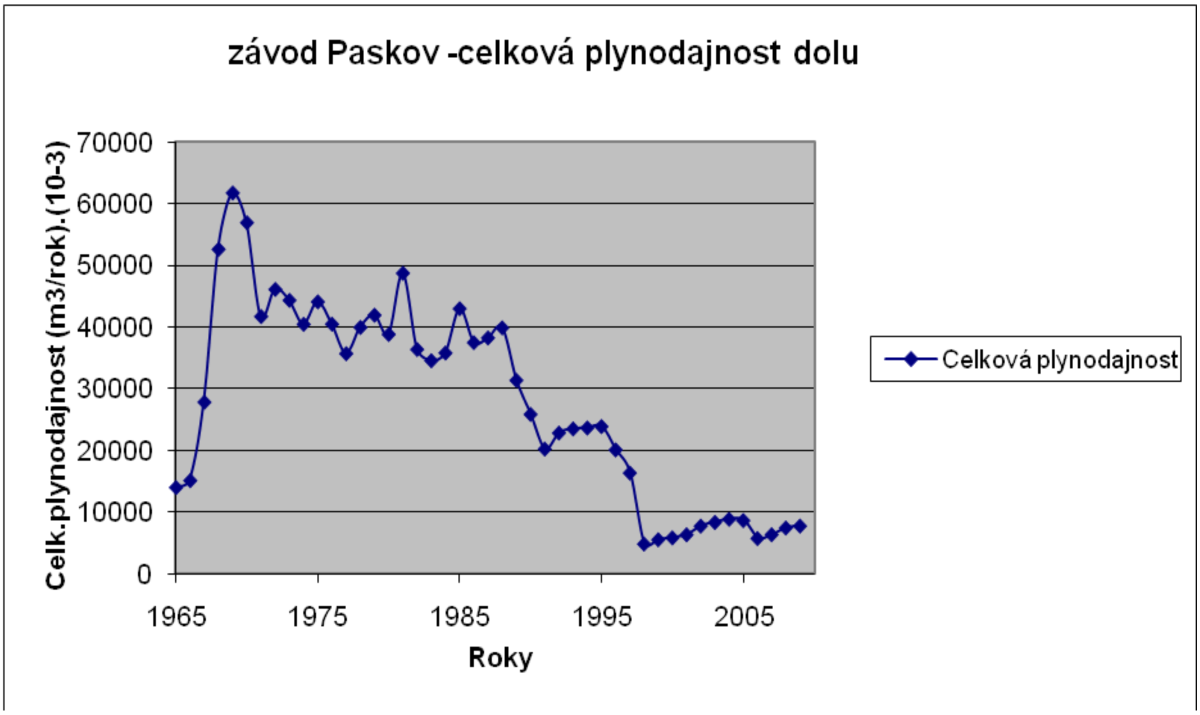
To illustrate situations at mines in the Ostrava-Karvina Coalfield two examples from the Paskov and Staric mines were chosen. Both originally separate mines are located in the southern part of the coalfield, and although being neighbours, they were not interconnected with any mine working. After 1989, the minor original Paskov Mine, with annual extraction of approximately 750,000 tons, was associated with the Staric Mine keeping the name Paskov Plant. Later the Staric Mine was renamed to Paskov Mine.

The graphs in Figures 2, 3 and 4, present the overall development of the total and residual gas capacities at both mines [5].



Staric Mine - total gas capacity
Total gas capacity ($m^3.year^{-1}$).(10^{-3})
Years
Total gas capacity

Fig. 2 Overall development of total gas capacities at the Staric Mine, now called the Paskov Mine.



Paskov Plant - total gas capacity
Total gas capacity ($m^3.year^{-1}$).(10^{-3})
Years
Total gas capacity

Fig. 3 Overall development of total and residual gas capacities at the Paskov Mine, now called the Paskov Plant.

Paskov Plant - residual gas capacity
Residual gas capacity ($m^3.year^{-1}$).(10^{-3})
Years
Residual gas capacity

Fig. 4 Detailed development of residual gas capacity at the Paskov Plant of the same Paskov Mine after its closure in 1999.

From the graphs in Figures 1, 2, 3 and 4 several findings can be derived:

The typical German mine in Figure 1 shows a total annual gas capacity value of $4.5.10^9$ m^3. The Staric Mine (today Paskov Mine) in Figure 2 shows after the run-up stage of mining operations since 1974 a total annual gas capacity value of $0.12.10^9$ m^3. The Paskov Mine after the run-up stage of mining operations since 1974 shows a total annual gas capacity value of $0.06.10^9$ m^3. Thus the total gas capacity of the Staric Mine (today Paskov Mine) is 37.5 x smaller than that for the typical German mine [1]. The total gas capacity of the Paskov Plant is even 75x lower than that for the typical German mine.

It is apparent from the graphs in Figures 1, 2 and 3 that during the extraction the total gas capacity of mine is gradually reduced. Figure 1 is probably somewhat idealized. Figures 2 and 3 indicate that the decline in gas capacity during the mining period is not uniform. There are some fluctuations, but the overall trend shows a decline.

The value of residual gas capacity that is of interest here just with regard to a possible utilization of gas reserves, may be derived from the total gas capacity at the end of the mining period. For the German mine in Figure 1 the residual gas capacity of 650.10^6 $m^3.rok^{-1}$ corresponds nearly to the value at the end of mining operations and within 10 years it decreased to 491.10^6 m^3. From these two figures we are not able to identify reliably the trends and determine the expected time when the gas reserves will run out to a useful level. If the course of decline in reserves is linear, then we would be able to estimate that by 35 years from completing mining operations the gas reserve would have run out.

However, the example of the Paskov Plant (Figure 4) offers a completely different course. Here during 11 years the gas reserves (residual gas capacity) grows. But in comparison with Figure 1 it is significantly lower, it achieves only $7.9.10^6$ $m^3.year^{-1}$. It is almost 80 times smaller than in the example of the German mine.

The potential energy of residual gas capacity at the Paskov Plant can be determined from the relation

$$P_{tep} = q \cdot Q \qquad (1)$$

where: P_{tep} - heat output of gas

q - calorific value of methane at a given concentration [$J.m^{-3}$]

Q - volume flow rate [$m^3.s^{-1}$]

At a concentration of 70% of methane-air mixture the gas achieves the calorific value
q = 25 000 $kJ.m^{-3}$ and if the volume flow rate is Q = 0,161 $m^3.s^{-1}$, then
P = 4 042 $kJ.s^{-1}$ = **4,04 MW**.

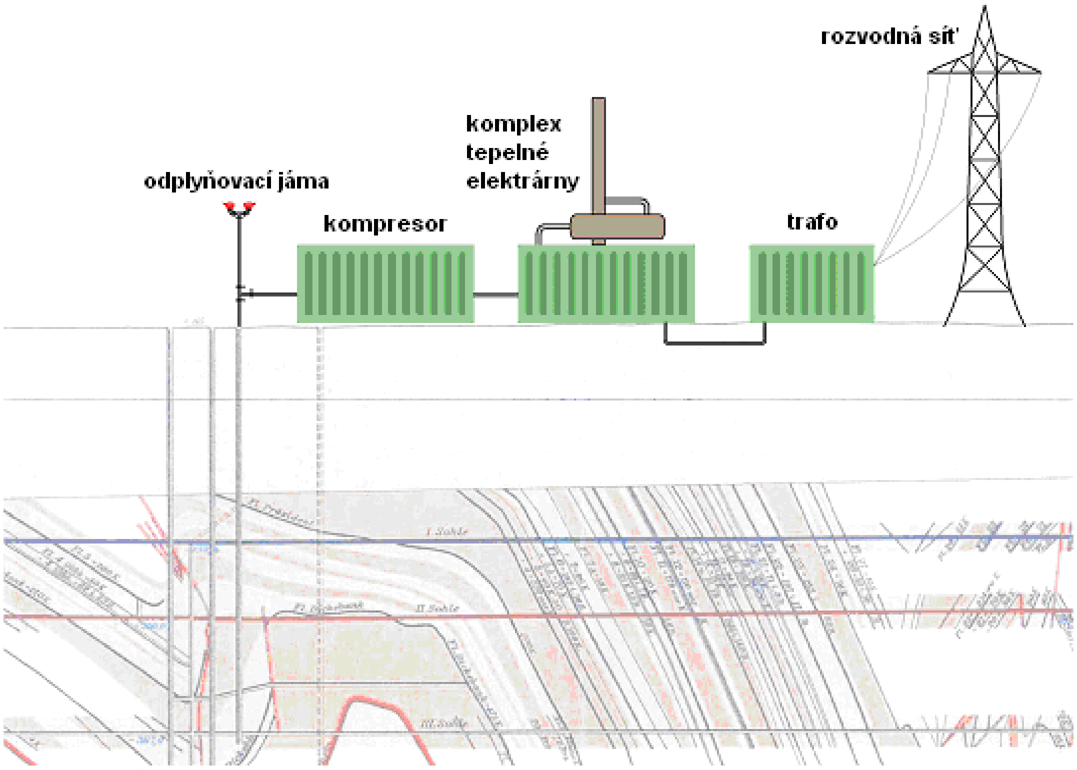
This is however a theoretical output only. The practical use will be significantly lower. As shown by experience, much energy is consumed for the output of a degassing station. Also, the distribution of heat and output needed to operate a cogeneration unit will absorb much of the theoretical power. Practically, the effective power of cogeneration on the units installed so far in the OKR varies from 0.5 to 1.5 MW.

3 SOME METHODS OF GAS ENERGY UTILIZATION

Draining methane from abandoned mines and degassing boreholes is one of the activities of the company Green Gas DPB, a.s. (formerly OKD DPB Paskov, a.s.). Mine gas is distributed through 130 km long pipeline to different customers, where it is used as a substitute for natural gas. Its overproduction had to be discharged into the air.

Newly introduced is the construction of facilities for electricity generation, the so-called cogeneration units. Their principle lies in the fact that the mine gas is a fuel for an reciprocating internal combustion engine that drives a generator to produce electricity. At the same time the thermal energy is produced in a cooling system, which can be delivered to customers in the close vicinity. Cogeneration units with power of 580 kW to 1600 kW deliver electricity to mains of the North Moravian Energetics and heat into heating systems in respective localities.

Schematically the mode of operation of the facility by [1] is given in Figure 5.



Degassing Shaft
Compressor
Complex of thermal power plant
Transformer
Grid

Fig. 5 Schematic representation of a method of utilizing gas from abandoned mines.

The success of this facility is also subject to an appropriate method of closing initial mine shafts. The term "appropriate method of closing" means leaving the degassing pipeline and taking it behind the gas stoppers at each level.

Currently operated or being prepared cogeneration units according to [4] in the Ostrava-Karvina Coalfield are as follows:

- Power of 580kW- Vrbice, Ostrava-Privoz, Fucik-Zofie.
- Power of 774 kW- Staric-Chlebovice, Dukla ,Lazy I.,II, Staric-Sviadnov.
- Power of 1.2 MW- Ostrava-Muglinov ,František I.
- Power of 1.6 MW- Staric–Staric, PaskovMines I,II,III, Frantisek I,II,Hermanice-Rychvald.

For that purpose a new organizational unit of Green Gas DPB Paskov a.s. has been established within the OKD, which by the end of 2009 built 21 cogeneration units with a total power of 34.1 MW.

The Cogeneration unit, type Tedom Quanto D 1200 SP NOC, is shown in Figure 6 and has the following parameters:

Cogeneration unit QUANT D 1200 SP CON:

electrical output 1169 kW
heat output 1339 kW
gas consumption 296 Nm3.h^{-1}
400 - 800 $m^3.hour^{-1}$ (at 30-50 % concentration of CH_4)

Fig. 6 Cogeneration unit QUANTO D 1200 SP NOC.

4 POSSIBILITIES OF UTILIZING GAS RESERVES FROM DEGASSING BOREHOLES

As is well known, tin the OKR larger quantities of degassing boreholes were established to protect the atmosphere and settlements. It offers therefore a logical question, whether the gas drained by these boreholes can also be economically exploited. Relatively reliable answer could be provided by the results of exhaust tests, which were for that reason performed at a number of boreholes. From the following overview, taken from [2 and 3], the following conclusions may now be deduced:

Results of exhaust tests in the locality of the Hrusov Mine

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Tab.1 Results of the MOS exhaust station operation at the Hrusov Mine

Time	Q [$m^3.h^{-1}$]	CH_4 [%]	CO_2 [%]	O_2 [%]	Suction (mm Hg)	Delivery (mm Hg)
18.9.2000 10:00	Operation commenced at HD6					
18.9.2000 10:00	100	56	7	0,5	70	5
18.9.2000 15:00	240	47,2	7,82	0,22	230	90
18.9.2000 20:00	240	44,9	7,87	0,25	230	90
19.9.2000 1:00	220	42,4	7,92	0,11	210	80
19.9.2000 6:00	220	41,4	7,97	0,16	215	110
19.9.2000 11:00	300	40,6	8	0,25	180	80
19.9.2000 16:00	300	39,6	8,05	0,4	180	80
19.9.2000 21:00	310	39,8	8,07	0,3	180	60
20.9.2000 2:00	300	40	8,2	0,2	175	54
20.9.2000 7:00	300	40,6	8,1	0,1	180	50
20.9.2000 8:45	MOS at HD6 shut down					
20.9.2000 15:00	Operation commenced at HD18					
20.9.2000 15:00	420	5	0,25	20,6	30	30
20.9.2000 20:00	230	19,7	7,75	10,47	30	100
21.9.2000 1:00	300	5	7,6	6,1	30	130
21.9.2000 6:00	300	4	7,2	7,2	28	120
21.9.2000 11:00	310	3,7	6,53	8,5	30	120
21.9.2000 11:30	MOS at HD18 shut down					
21.9.2000 15:30	Operation commenced at HD1					
21.9.2000 20:00	470	43	8,3	0	30	30
22.9.2000 1:00	360	40,8	8,1	0,2	24	28
22.9.2000 6:00	370	38,3	8,4	0,1	20	20
22.9.2000 11:00	370	35,8	8,5	0,1	20	30
22.9.2000 16:00	450	33,1	8,51	0,12	25	35
22.9.2000 21:00	300	30,3	8,95	0,3	15	17
23.9.2000 2:00	300	27,9	8,61	0,58	15	17
23.9.2000 7:00	270	26	8,6	0,9	15	18
23.9.2000 10:00	300	24,5	8,6	1	15	25
23.9.2000 10:00	MOS at HD1 shut down					

It results from Table 1 that during the exhaust tests running in the days of 21th – 23rd September 2000 the exhaust station was gradually connected to the boreholes HD6, HD18 and HD1.

While evaluating the energy potential of the gas acquired during exhausting only the theoretical parameters, namely the needful power of the exhausting equipment and gas energy, are assessed.

From table 1 we find that at the borehole HD6 for the whole exhaust period (45 hours), a relatively stable concentration of CH4 (40%) was kept, but the required depression of the MOS exhaust unit had to be 26,600 Pa. With an average volume flow rate Q = 300 $m^3.h^{-1}$ the required exhaust power of the unit is as follows:

P = 2 216 W

The expected energy utilization would be at the 40% concentration of CH4 according to the equation (1) as follows

P_{tep} = 12 000 kJ.m^{-3}.300 m^3.$hour^{-1}$ = 3,6.10^6 kJ.h^{-1} = 1 000 kJ.s^{-1} = **P_{tep} = 1 000 kW.**
By analogy for the borehole HD1
P = 222 W
P_{tep} = 8 706 kJ.m^{-3}.300 m^3.$hour^{-1}$ = 725 kJ.s^{-1} **P_{tep} = 725 kW**

At the HD18 borehole there is so low methane concentration that the economic recovery could not be considered.

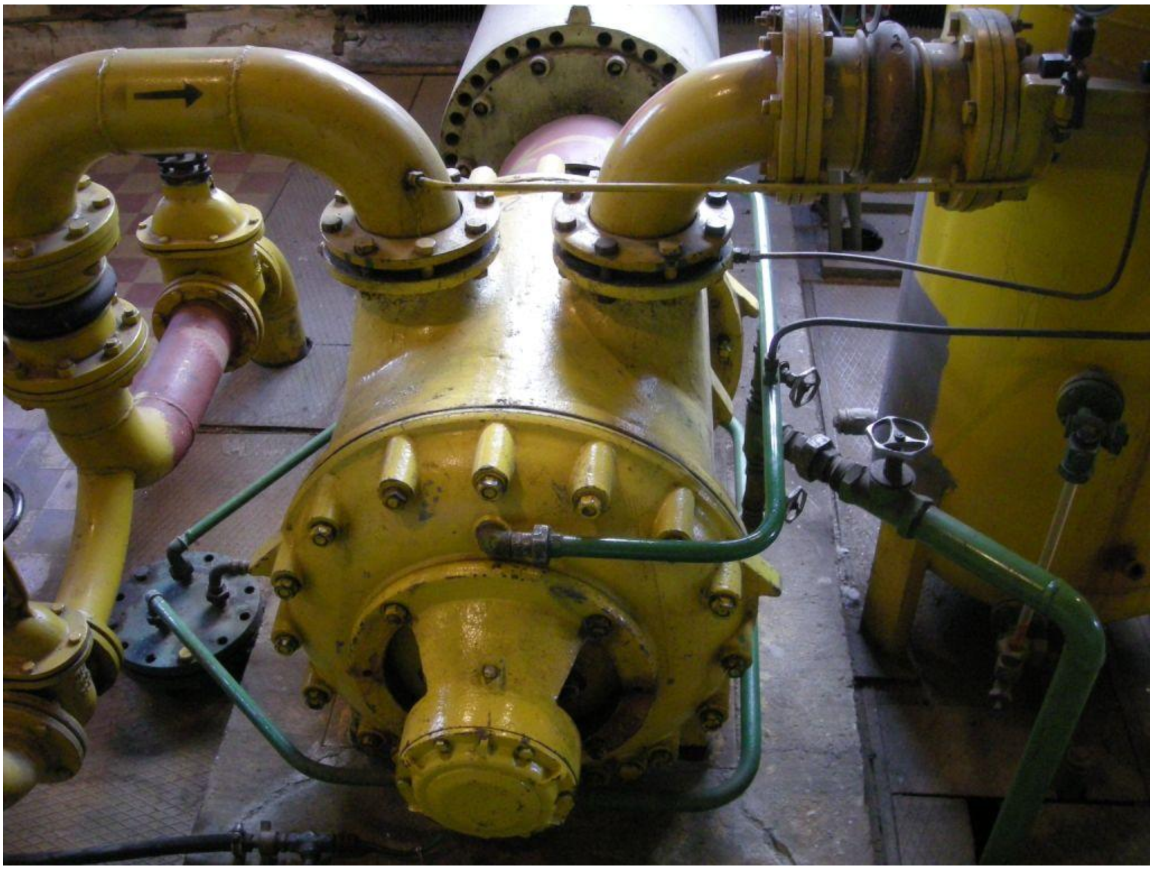

Fig. 7 Degassing (exhaust) station - water-ring pump RLP 62-73.

Comparison of the results of exhaust tests at the Hrusov Mine below indicates an economic efficiency of obtaining gas from the boreholes HD1 and HD6. However, it is necessary to mention that we come out here from a shorter duration of the exhaust test only. At the HD6 borehole considering the required high depression of the exhausting plant we gather the gas from a relatively narrow space (storage). At the HD1 borehole again a significant decrease of the methane concentration (from 43% to 24,5%.) occurs during the 38-hour test. In the given situation of the Hrusov Mine at the borehole depth below 60 m the gas utilization is not real.

As for the results of exhaust tests in other locations, I assess them just very briefly, because the conclusions are similar as in the case of boreholes at the Hrusov Mine.

Exhaust test results in the area of the Jakovlecky Mine.

The exhaust test took place for the period of 24 hours in October 14-15, 2002.

The exhaustion at the Jd14 borehole was carried out with a relatively small depression of 800 Pa, with an average volume flow rate Q = 470m3.h-1. However the CH4 concentration did not exceed 20%, so utilizing the energy potential could not be considered.

At the Jd30 borehole, where the exhaust test was performed also for the period of 24 hours, the methane concentration was zero throughout the test.

Exhaust test results in the area of Petrkovice.

Relatively favourable results the exhaust test showed at the MV39 borehole. The exhaustion took place for the period of 70 hours from May 26, 2003 to May 29, 2003. The average values were as follows. The exhaust plant depression was 2130 Pa, volume flow rate 500 $m^3.s^{-1}$, methane concentration 40 %.

Analogous results were found out also at the MV40 borehole. The exhaustion took place for the period of 24 hours from October 16, 2002 to October 17, 2002. The average values were as follows. The exhausting plant depression was 533 Pa, volume flow rate 260 $m^3.s^{-1}$, methane concentration 46 %.

The results at both boreholes give certain premises of the gas utilization for energy purposes.

Exhaust test results in the area of Orlova.

The exhaust tests were carried out at the boreholes OV5, OV6, OV7, OV11 and MOV2.

At MOV2 a shorter test was performed on 30th May 2002 for the period of 4 hours. The average values were as follows. The exhausting plant depression was 799 Pa, volume flow rate 90 $m^3.s^{-1}$, methane concentration 30 %.

The exhaust test at OV5 took place for the period of 40 hours from May 27, 2002 to May 29, 2002 with the following results. The exhausting plant depression ranged from 399 to 933 Pa, volume flow rate was from 15 to 240 $m^3.s^{-1}$, methane concentration from 45 to 20 %.

The exhaust test at OV6 took place for the period of 44 hours from July 30, 2002 to August 1, 2002 with the following results. The exhausting plant depression was 933 Pa, volume flow rate 300 $m^3.s^{-1}$, methane concentration 12 %.

The exhaust test at OV7 took place for the period of 48 hours from August 12, 2002 to August 14, 2002 with the following results. The exhausting plant depression was 133 Pa, volume flow rate was from 90 to 350 $m^3.s^{-1}$, methane concentration ranged from 32 to 0 %.

The exhaust test at OV11 took place for the period of 48 hours from May 29, 2002 to May 31, 2002 with the following results. The exhausting plant depression ranged from 266 to 5,332 Pa, volume flow rate was from 40 to 90 $m^3.s^{-1}$, methane concentration from 42 to 0 %.

Partial conclusion to the results of the exhaust tests.

It follows from the presented overview that except for the Petřkovice locality the results of the exhaust tests do not give a prerequisite to an economic utilization of the gas from underground areas of abandoned mines. However, this result has been obtained from the results at degassing boreholes whose depth did not exceed 60 m. The work [2] shows findings, according to which at a greater depth of degassing boreholes (see the experience from Germany), the production of gas from underground areas can increase significantly. We have not so far dealt with these options in our practice. With regard to a possible acquisition of certain energy sources, it would be suitable to verify this option.

5 CONCLUSION

The paper assesses possibilities of obtaining gas energy from abandoned underground areas of coal mines in the Ostrava-Karvina Coalfield. If original shafts are used for this purpose, it may be possible at an appropriate technical arrangements to get the gas through degassing stations and distribute it either as heat or electric energy. In this case it is necessary to leave in the original shafts before their closure the degassing pipelines, taken out at each level behind the gas stoppers.

To obtain the gas energy from degassing boreholels it would be appropriate to examine, whether the increased gas capacity may be acquired by their deepening up to the depths, where last mining operations took place.

REFERENCES

[1] Dr.-Ing. Heribert Meiners, Dipl.-Ing. Michael Opahle, DMT GmbH *Gaspotential, Gasfassung und Gasverwertung in aktiven ud geschlossenen Bergwerken 2007.*

[2] PROKOP, P.: Možnosti pro využití zásoby plynu v uzavřeném podzemí jako zdroje energie. Sborník vědeckých prací HGF VŠB-TU květen 2008.

[3] Výsledky měření v terénu, zejména na odplyňovacích vrtech a během odsávacích zkoušek, v průběhu řešení Grantového úkolu č. 105/98/KO45. VŠB-TUO, říjen 2003.

[4] VAVRUŠÁK, Z.: Informace o aktivitách společnosti Green Gas International Limited. Horník č.23/2008.

[5] URBAN, P.:Odsávání a využití plynu z utlumovaného dolu-závod Paskov, Důl Paskov, o. z. OKD, a.s. *Sborník příspěvků-Mezinárodní konference „Nerostné suroviny a hornická činnost 21. století“. Ostrava, VŠB-TU Ostrava,2001.*

RESUMÉ

Nalezení způsobu a možnosti získávání energie využíváním důlního plynu z uzavřeného podzemí zlikvidovaných uhelných dolů v ostravsko-karvinském revíru, který na mnoha místech nekontrolovaně vystupuje na povrch, se jeví jako jedno z nejpřijatelnějších řešení.

Odsávání plynu z podzemí a jeho rozptyl do ovzduší není ekologicky únosné. Zpracování tohoto plynu zase přináší nutnost poměrně velkých investičních nákladů.

Na základě zhodnocených možností přicházíme k závěru, že právě využívání metanu z podzemí uzavřených dolů formou přeměny na tepelnou a elektrickou energii je výhodným řešením, které navíc přináší rychlou návratnost vložených prostředků a je nejméně ekologicky zatěžující.