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ESTABLISHMENT OF GAS OUTLETS FROM UNDERGROUND THROUGH ACCUMULATIVE CHAMBER

ZJIŠŤOVÁNÍ VÝSTUPŮ PLYNŮ Z PODZEMÍ AKUMULAČNÍ KOMOROU

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Abstract

This paper evaluates the application of accumulative chamber for finding gas flow relations from abandoned mine through rock environment. It was proved that only in a few cases minimum values of volume flow are registered. This demonstrates that the escape of gas only occurs in the areas with suitable communication.

Abstrakt

V předloženém článku se posuzuje aplikace akumulační komory ke zjištění zákonitostí proudění plynů z uzavřeného podzemí, přes horninové prostředí. Bylo ověřeno, že jen v omezeném počtu případů jsou registrovány alespoň minimální hodnoty objemového průtoku. To dokazuje,že k výstupům plynů dochází jen v oblastech s vhodnou komunikací.

Key words: Gas outlet, abandoned mine, accumulative chamber, drainage borehole

1 INTRODUCTION

Apparently, gas outlets from underground of abandoned mines caused many problems. One of them was the accumulation of dangerous concentration of methane on the exposed area surface. The situation was even worse if the gas concentrated in unventilated premises of building sites. To solve the above situation, it was necessary to establish the gas escape from the underground through layers located above the coal-bearing formation. A lot of research work was done for this purpose. The submitted paper presents a brief outline of results achieved by means of the accumulative chamber.

2 METHODS OF ESTABLISHING GAS OUTLETS FROM ABANDONED MINES

After the first indications of dangerous gas escape from abandoned mines, the organisations responsible took a number of measures. An important one involved the execution of various types of boreholes. The effort particularly focused on drainage boreholes aimed at the organised drainage of gases from the places of their increased concentration. This hypothesis was partly proved in practice; in many cases, however, the expected drainage was not successful. Nevertheless, this method of protection, based on the drainage of gases through drainage boreholes owing to the pressure difference between the underground and surface, found an extensive application. At present, more than a hundred boreholes of this type are established in the Ostrava-Karviná coal district. As the degassing effect is merely based on the impact of the natural pressure difference, this system of protection is denoted as “passive”. For details, see [1].

It was proved recently (2007) that a degassing piping left in the original pits may have a significant influence on the outlet of underground gas storage. Therefore, systems appear for exhausting the gas on the basis of drainage systems depression. The energy of gas obtained in this way is exploited economically in most cases – either as a source of heating or to obtain electric energy by means of co-generating units.

To establish the gas outlet through rock layers directly, the atmogeochemical method is applied quite extensively. Its principle is based on the execution of shallow (1.1 m) deep boreholes in which the methane concentration is measured. To get a deeper insight into the patterns of gas outlet through rock layers, the Czech Mining Institute (ČBÚ) initiated a task to measure not only concentration, but also the escaping gas volume flow. Finding both of these factors undoubtedly contributes to determining important properties of the gas produced in the environment given. For this purpose, the measurement by means of the accumulative chamber was applied.

2.1 Area in which the method of establishing gas outlets through accumulative chamber was applied

For the application of the method of establishing gas outlets through rock layers, a locality was selected in the Orlová historical town centre. Numerous gas escapes occurred in this area in the past, even at the time of the measurement mentioned. Many of them were evaluated as emergency ones. The gas endangered residential areas, building basements, sewerage systems and produced even in public places through the earth. A number of degassing boreholes were drilled in the locality to control the conditions. Fig. 1 gives an outline of the area with other details, including some of the degassing boreholes.

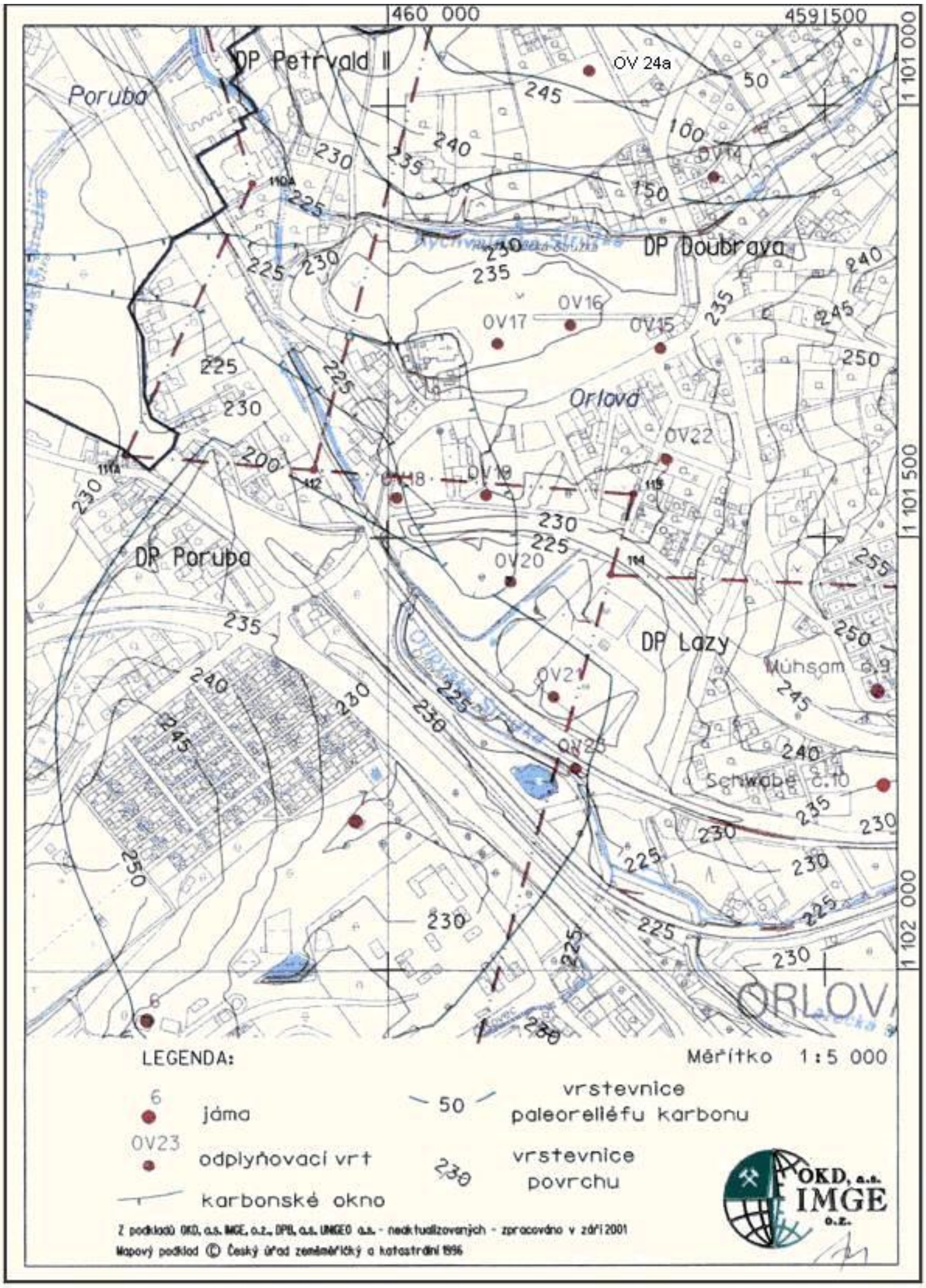

Fig No. 1 Situation in the Orlová locality in which the measurement was done by means of the accumulative chamber.

2.2 Basis of the method and way of measurement

The method consists in the creation of a closed aboveground space, as tight as possible, with unaffected conditions for gas outlet. The outlet intensity of the methane and carbon dioxide gases escaping to the surface through the earth is determined by measuring the volume flow of gas from a surface unit per time unit in $cm^3.min^{-1}.m^{-2}$. The measuring range of the gas surface outlet intensity (flow) depends on the analytical equipment used and the measured gas type. In case of methane, for example, a detector of the sensitivity of 1 ppm enables measurement of flows within the range of 0.1 – 4 000 $cm^3.min^{-1}.m^{-2}$. For details, see [2].

Division of the area by a square grid and measuring the flow values in its individual points presents the first stage in the process of determination the total gas emission.

Projecting the measurement, one must take into account the geological bases and results of field investigation, which influence the gas outlet, and adapt the measuring point location accordingly.

With view to the unavailability of special measuring equipment in the Czech Republic, the below measurements were done according to the Contract of Works with the research institute of INERIS, France. *I participated in the project preparation and evaluation personally and largely exploited the obtained knowledge in this paper as well. For details, see [3].*

The measurement was executed on June 16-18, 2003. The measuring system, composed of an accumulative chamber made of acrylic glass in an aluminium frame, a portable analyser CH_4, recorder and pressure cylinders with calibrated gas, features a simple operation. The total time for one measurement falls within the range of 5-10 min, so a great number of measurements can be done in one day (from 40 to 60 points, according to the field configuration).

In case of methane measured with the sensitivity of 1 ppm, flows from 0.05 to 4,000 $cm^3.min^{-1}.m^{-2}$ can be measured. The flow of methane escaping from the area delimited by the accumulative chamber is calculated on the basis of the time increase in the chamber gas concentration recorded by the recorder.

Fig. No. 2 shows the accumulative chamber diagram.

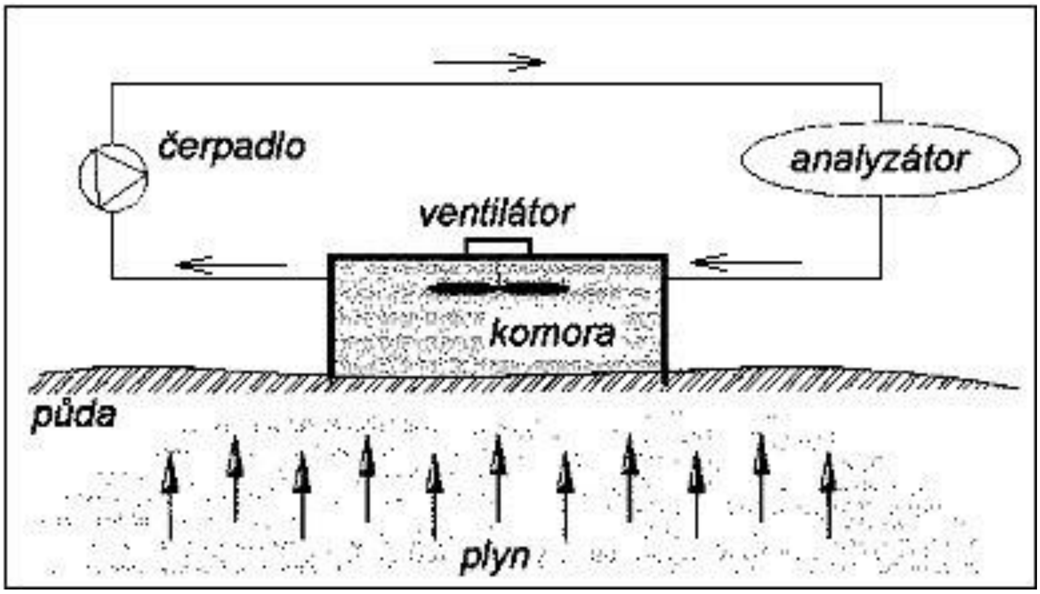

Fig No. 2 Accumulative chamber diagram

čerpadlo	pump
ventilátor	fan
analyzátor	analyser
komora	chamber
půda	earth
plyn	gas

Technical parameters of the INERIS equipment:

Chamber volume:	30 l
Dimensions:	0.7 x 0.7 m
Analyser sensitivity:	1 ppm
Detection limit:	0.005 N $cm^3.min^{-1}.m^{-2}$
Measuring range:	0.05-4 000 N $cm^3.min^{-1}.m^{-2}$
Measuring time:	1-3 min

Fig. No. 3 is a photograph of the INERIS equipment used in the locality.

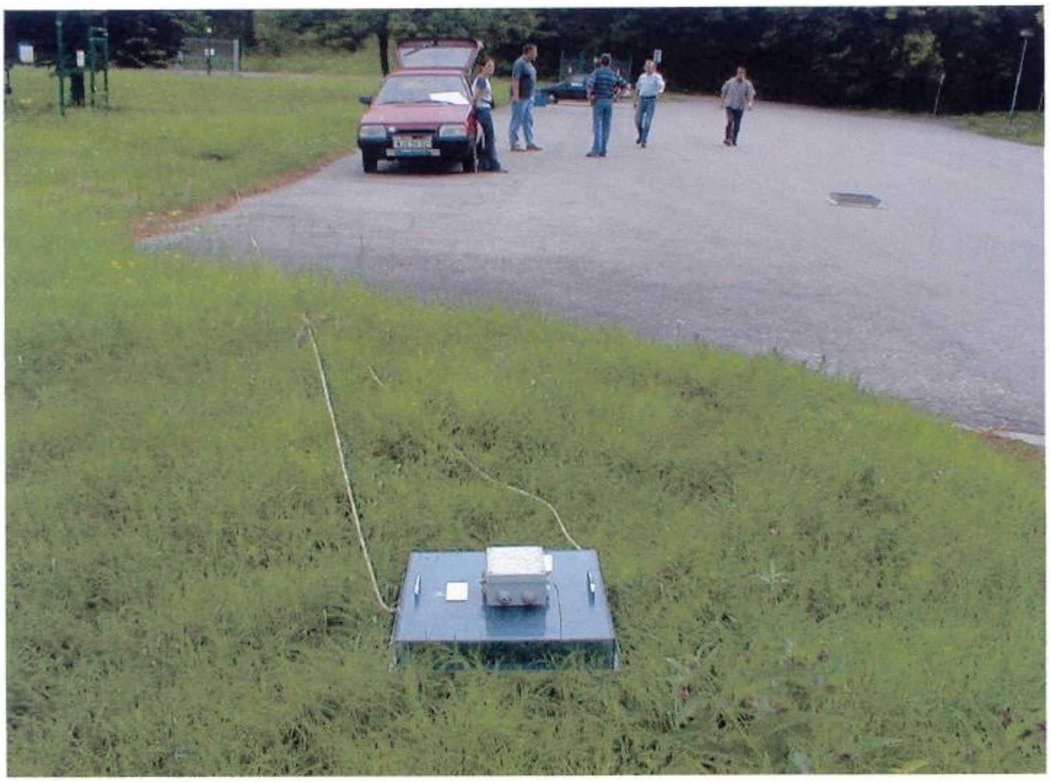

Fig. No. 3 Photograph of the INERIS equipment used in the locality

The measurement was done in the period of low barometric pressure, with values at which the gas escapes from the underground – Table No. 1.

Table No.1 Development of barometric pressure in the time of measurement

Date	June 16, 2003		June 17, 2003		June 18, 2003		
Hour	0	12	0	12	0	12	24
Barometric pressure	1008	1007	1007	1010	1009	1010	1009

In sum, 149 positions were measured. Out of this large set of measured values, I only selected for further evaluation the positions at which even the minimum values were found. Positions of zero value (majority) are not stated here. The result is in Table No. 2.

I pre-analysed the measurement results in Table No. 2. According to the INERIS technical parameters, I converted the corrected flow in ($cm^3.min^{-1}.m^{-2}$) to ($m^3.s^{-1}$). To convert ($cm^3.min^{-1}.m^{-2}$) to ($m^3.s^{-1}$), ($cm^3.min^{-1}.m^2$) must be divided by (106.60) and the result multiplied by (0.49). Simultaneously, using the equations (1) and (2), I calculated the rock formation permeability to which these values correspond.

Table No. 2 Corrected flow found by the INERIS apparatus, converted to volume flow in ($m^3.s^{-1}$), and calculated permeability at measuring points at which corrected flow values were found higher than 0.

Position	Corrected flow ($cm^3.min^{-1}.m^{-2}$)	Volume flow ($m^3.s^{-1}$)	Permeability (m^2), by equation (1)	Permeability (m^2), by equation (2)
111/1	9,3	$7{,}59.10^{-8}$	$6{,}38853.10^{-13}$	$3{,}19171.10^{-8}$
111/2	9,1	$7{,}43.10^{-8}$	$6{,}25114.10^{-13}$	$3{,}12307.10^{-8}$
133	0,73	$5{,}96.10^{-9}$	$5{,}01465.10^{-14}$	$2{,}50532.10^{-9}$
132	0,18	$1{,}47.10^{-9}$	$1{,}23649.10^{-14}$	$6{,}17751.10^{-10}$
330	0,64	$5{,}22.10^{-9}$	$4{,}39641.10^{-14}$	$2{,}19645.10^{-9}$
331	0,30	$2{,}45.10^{-9}$	$2{,}06082.10^{-14}$	$1{,}02958.10^{-9}$
335	41,1	$3{,}35.10^{-7}$	$2{,}82332.10^{-12}$	$1{,}41053.10^{-7}$
336	14,1	$1{,}15.10^{-7}$	$9{,}68584.10^{-13}$	$4{,}83905.10^{-8}$
342	29,6	$2{,}42.10^{-7}$	$2{,}03334.10^{-12}$	$1{,}01586.10^{-7}$
343	0,77	$6{,}28.10^{-9}$	$5{,}28943.10^{-14}$	$2{,}6426.10^{-9}$
344	11,1	$9{,}06.10^{-8}$	$7{,}62502.10^{-13}$	$3{,}80946.10^{-8}$
348	2,2	$1{,}8.10^{-8}$	$1{,}51127.10^{-13}$	$7{,}55029.10^{-9}$
350	12,6	$1{,}03.10^{-7}$	$8{,}65543.10^{-13}$	$4{,}32425.10^{-8}$
472	13,6	$1{,}11.10^{-7}$	$9{,}34237.10^{-13}$	$4{,}66745.10^{-8}$
473	0,51	$4{,}16.10^{-9}$	$3{,}50339.10^{-14}$	$1{,}75029.10^{-9}$
475	0,41	$3{,}35.10^{-9}$	$2{,}81645.10^{-14}$	$1{,}4071.10^{-9}$
476	0,21	$1{,}71.10^{-9}$	$1{,}44257.10^{-14}$	$7{,}20709.10^{-10}$
181	0,30	$2{,}45.10^{-9}$	$2{,}06082.10^{-14}$	$1{,}02958.10^{-9}$
503	0,09	$7{,}34.10^{-10}$	$6{,}18245.10^{-15}$	$3{,}08875.10^{-10}$
504	0,18	$1{,}47.10^{-9}$	$1{,}23649.10^{-14}$	$6{,}17751.10^{-10}$
508	0,18	$1{,}47.10^{-9}$	$1{,}23649.10^{-14}$	$6{,}17751.10^{-10}$
519	0,06	$4{,}9.10^{-10}$	$4{,}12163.10^{-15}$	$2{,}05917.10^{-10}$
534	0,50	$4{,}08.10^{-9}$	$3{,}43469.10^{-14}$	$1{,}71597.10^{-9}$
537	0,08	$6{,}53.10^{-10}$	$5{,}49551.10^{-15}$	$2{,}74556.10^{-10}$
538	0,09	$7{,}34.10^{-10}$	$6{,}18245.10^{-15}$	$3{,}08875.10^{-10}$
540	20,1	$1{,}64.10^{-7}$	$1{,}38075.10^{-12}$	$6{,}89822.10^{-8}$
542	5,3	$4{,}32.10^{-8}$	$3{,}64078.10^{-13}$	$1{,}81893.10^{-8}$
543	15,9	$1{,}3.10^{-7}$	$1{,}09223.10^{-12}$	$5{,}4568.10^{-8}$
544	0,19	$1{,}55.10^{-9}$	$1{,}30518.10^{-14}$	$6{,}5207.10^{-10}$
545	23,6	$1{,}93.10^{-7}$	$1{,}62118.10^{-12}$	$8{,}0994.10^{-8}$
546	0,24	$1{,}96.10^{-9}$	$1{,}64865.10^{-14}$	$8{,}23668.10^{-10}$
547	0,61	$4{,}98.10^{-9}$	$4{,}19033.10^{-14}$	$2{,}09349.10^{-9}$
549	0,09	$7{,}34.10^{-10}$	$6{,}18245.10^{-15}$	$3{,}08875.10^{-10}$

To calculate the gas permeability of the rock (earth) layer, I used a simplified form of the Darcy equation (1) and (2)

$$Q = \frac{S.(p_s - p_0).k_l}{\eta.z} \qquad [m^3.s^{-1}] \qquad (1)$$

$$Q = \frac{S.(p_s^{\ 2} - p_0^{\ 2}).k_1}{\eta.p_0.z} \qquad [m^3.s^{-1}] \qquad (2)$$

The measurement area S (m^2) of 70x70 cm was derived from the technical conditions; according to the previous results of measuring at the degassing boreholes, dp is 9 to 160 Pa (where p_s is the internal underground gas pressure [Pa] and p_0 is the barometric pressure [Pa]). I applied the value of 160 Pa; by experience, "z" is 60 m at most, which is the depth below surface [m].

Thus S = 0.7 x 0.7 = 0.49 m^2, $p_s - p_0$ = 160 Pa, $\eta = 1{,}1.10^{-5}$ Pa.s (dynamic viscosity of the gas).

Such low values of volume flows as given in Table 2 were not recorded in the exposed areas. At the boreholes measured in Orlová, the values typically amounted to 10^{-3}, or at least to 10^{-4} $m^3.s^{-1}$.

The possible explanation is that the rock, cover and earth at the place of measurement are really almost impermeable and the gas only communicates to the surface by ways with higher gas permeability: tectonic faults, boreholes, old mining workings.

The result according to the equation (1) seemed very low to me. Therefore, I tried the procedure by (2), which is also stated in literature. [1].

The results are in Table No. 2. Preliminarily, the permeability according to (2) seems to be 4 to 5 decimal points higher. Very low volume flows, such as those found in the INERIS case, will probably necessitate application of the procedure by the equation (2).

In my opinion, the procedure by (2) is probably satisfactory and the permeability values are really so low across the entire, little disturbed mining environment up to the surface. I was confirmed by the results of the INERIS measurement, at which 116 out of the 149 positions at which we executed the measurement featured zero values of corrected flow. That means that the permeability theoretically equals to zero there.

For comparison according to [3], I present the methane concentrations measured by the methane-screening method, OKD, DPB, a.s., the values are indicated in Table No. 3.

Table No. 3 Corrected flow and methane concentration in Orlová on June 16 and 17, 2003

Position	Corrected flow ($cm^3.min^{-1}.m^{-2}$)	Concentration of CH_4 (ppm)
280b	0.0	4 000
282b	0.0	1 800
336	14.1	3 200
472	13.6	6 000

It cannot be explained yet how the given methane concentration may have occurred at the positions with the corrected flow of 0 ($cm^3.min^{-1}.m^{-2}$). I attribute it to possible inaccuracies of measurement at such low values of the corrected flow.

In the next stage of solution, it will probably be useful to concentrate on the borehole results.

The measurement of position 534, for example, revealed the corrected pressure of 0.50 $cm^3.min^{-1}.m^{-2}$, which is, after conversion, $4.08.10^{-9}$ $m^3.s^{-1}$.

In close vicinity of this position 534 is the borehole OV12. According to recent measurements, its volume flow is 53.7 $m^3.hod^{-1}$, that is 0.0149 m^3s^{-1} = $1.49.10^{-2}$ $m^3.s^{-1}$, which is a value higher by 7 decimal points than the value measured by the accumulative chamber..

A probable conclusion seems to be that the gas communication to the surface only occurs through the zones of tectonic faults, irregularities in the mining environment, boreholes and old mining workings.

Nevertheless, the method of simultaneous measurement of volume flow and concentration of the escaping gas (methane), as enabled by the INERIS equipment, provides wide possibilities of quicker and more reliable establishment of patterns of gas outlet from the abandoned mine underground.

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3 CONCLUSION

To obtain more detailed knowledge on the gas communication from the closed underground through rock layers, especially earth, the measurement was done by means of the accumulative chamber of the INERIS type. The results achieved do not yet enable an unambiguous answer to the questions connected with the problem. Preliminarily, the immediate rock layer at a small depth below the surface seems to have such a low permeability at the evaluated places that this flow is hindered. At the same time, however, the comparison of results found by the INERIS chamber with those determined at the boreholes in close vicinity to the positions at which measurements were done by the accumulative chamber indicates the following: the gas outlets produce at higher depths (over approx. 5 m) and occur after suitable communication. Tectonic faults, old mining workings, occurrence of layers with higher gas permeability. This finding only documents the phenomenon complexity and also requires application of the method based on the accumulative chamber function to detect the above danger.

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RESUMÉ

Současné vědomosti a zkušenosti o panujících plynových podmínkách pod zemským povrchem po ukončení těžby uhlí ukazují, že tyto podmínky nejsou zcela prozkoumány. V době těžby uhlí deprese hlavních důlních ventilátorů a případná degazace zamezovala možnosti nekontrolovanému výstupu podzemní atmosféry na povrch.

Nadloží vyrubaných prostor až po samotný povrch je prostředí z mnoha různých příčin diskontinuitní, tedy protkáno řadou ploch nespojitosti vzniklých vlivem poddolování, tektonických poruch, uměle vytvořených důlních děl, vrtů, odkrytých karbonských oken, tedy topografických ploch s nízkou vrstvou pokryvu, resp. ploch s pokryvem zcela denudovaným, ale také ploch vzniklých umělým zásahem do nejsvrchnějších partií zemského povrchu nesouvisejících přímo s důlní činností (podpovrchové komunikace, kanalizace, energovody, vodovody, plynovody, parovody, atd.).

Z vlastního rizika nebezpečí výstupu důlních plynů na zemský povrch vyplývá, že je zapotřebí najít prostředky pro jeho eliminaci. K tomuto účelu slouží i schopnost měření vystupujícího plynu z podzemí. Na tento problém je zaměřen článek „Zjišťování výstupu plynů z podzemí akumulační komorou“.