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AIR CONDITIONING IN MINES IN THE CZECH REPUBLIC AND UKRAINE

PROVJETRAVANJE U RUDNICIMA REPUBLIKE ČEŠKE I UKRAJINE

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Abstract

The present-day micro-climatic conditions in black coal mines are of such nature that in no mine natural micro-climate conditioning is sufficient any more. The original temperature of rocks grows progressively in dependence on the increasing depth of the extracted seam, or more precisely, on the mining workplace, and this growth is much more significant than previously considered. The temperature of the surrounding rocks, but also high-performance continuous miners and conveyor belt drives heat up airflow, thus worsening microclimatic conditions.

This article describes micro-climatic conditions the in Czech Republic and Ukraine and some methods of deep mines air conditioning..

Sažetak

Današnji mikroklimatski uvjeti u rudnicima bituminoznog ugljena su takvi da prirodni mikroklimatski uvjeti ni u jednom rudniku više nisu zadovoljavajući. Ležišna temperatura stijena raste progresivno s povećanjem dubine eksploatacijskog sloja ili preciznije mjesta dobivanja i taj rast je značajniji od prethodno razmatranog. Temperatura okolnih, pratećih stijena, ali također i visokoučinkoviti strojevi za kontinuirano dobivanje i pogon transpotnih traka zagrijavaju zračnu struju i tako dodatno pogoršavaju mikroklimatske uvjete.

Rad opisuje mikroklimatske uvjete u podzemnim ugljenokopima Republike Češke i Ukrajine i neke metode provjetravanja dubokih rudnika.

1. Microclimatic Conditions in OKD, a.s. (Ostrava - Karviná Mines, s.c.)

The temperature of rocks reaches as much as 50 $^{\circ}C$ at the lowest levels of mines. Similarly, the values of geothermal gradient, or geothermal grade change progressively with the increasing depth. While designing lower levels in mines, the average geothermal gradient value of $G_{gr} = 0{,}033\ [K \cdot m^{-1}]$ obtained by calculating from the rock temperatures measured in the depths of -500 to 800 m was taken into account so far, while from the last measured rock temperatures in the lowest levels of active mines, the resulting value for the depth of 1 000 m is 0.045 $[K \cdot m^{-1}]$, and for the depth 1.200 m, the geothermal gradient value calculated by the program is 0.055 $[K \cdot m^{-1}]$ (Fiurášková 2010). The values of other factors determining or significantly affecting adverse mine microclimate are rising. Consequently, for example it is not possible to increase the airflow volume efficiently enough. It is hindered by e.g. airflow speed limit in coal faces. Besides, coal face ventilation systems are settled, and introducing different systems is accompanied by further complications, there is also a limit in connection with decreasing the relative air humidity. (Klanfar et al. 2010)

1.1. Cooling Methods

Cooling equipment in OKD, a.s. utilizes cooling technologies based on evaporation of refrigerant in condensation evaporators. The cooling equipment used can be divided according to:

- the way of cool transmission into mine airflow:
  - a) mobile with direct cooling,
  - b) stationary with indirect cooling
- the way of conduction of condensation heat (of the consumed energy by the compressor) with:
  - a) an open circuit of cooling water
  - b) a closed circuit of cooling water
- location:

a) local (mobile),
b) sectional,
c) central (located in a mine, or on the surface).

The following basic cooling systems are used in OKD, a.s.:

- Mobile sectional ones with direct cooling and an open circuit,
- Mobile sectional ones with direct cooling and a closed circuit,
- Stationary multi-level ones with indirect cooling when the cooling device is stationary and airflow coolers are mobile,
- Central ones with surface cooling.

1.1.1. Mobile Sectioanl System with Direct Cooling and Open Circuit

The mobile sectional systems with direct airflow cooling with an open circuit means, that the conduction of condensation Heat is realized by drain

Advantages and disadvantages of this implementation:

- The installation time is considerably shorter than with stationary systems or closed circuits.
- Financial demands are lower than with central multi-level stationary systems with indirect mine airflow cooling. The period between establishing the need for mechanical cooling until putting the system in commission is very short.
- It places higher technical demands on operation in the coalfield, because it is not concentrated in one area. There is a need for higher number of technically skilled operating staff.
- With respect to conduction of condensation heat from the workplace, it has a highly adverse impact on the follow-up workplace.
- Using water for sprinkling results in higher humidity and it can also worsen the workplace upcast microclimatic conditions.
- Mine premises are limited in terms of space, thus determining the size of cooling equipment that can be used.

Figure 1 Mobile cooling unit IDV 600

Slika 2. *Mobilna jedinica za hlađenje IDV 600*

1.1.2. Mobile Sectional System with Direct Cooling and Closed Circuit

Advantages and disadvantages of this implementation:

- With minor adjustments, similar conditions apply to this system as to the above mentioned one, except that the investment costs rise by the cost of reflux condensers and cooling water pipe.
- If reflux condensers for conduction of condensation heat are appropriately located, the impact on improving microclimatic conditions is more favourable than with an open circuit

Figure 3 Reflux condenser of mine airflow RWK 300

Slika 4 *Refluks kondenzator zračne struje rudnika RWK 300*

1.1.3. Stationary equipment (Multi-Level) with Indirect Cooling

Stationary sectional (Multi-Level) with indirect cooling of mine airflow means, that the machine is stationary and the airflow condensers are mobile.

Advantages and disadvantages of this implementation:

- The equipment installation requires specially built and equipped premises, or spatial adjustment of workings.
- Installation requires qualified specialists.
- During the equipment operation there are much fewer breakdowns, because technically demanding devices are stationary at one point and they are not moved.
- The airflow condenser is a very simple device, operating staff does not need to be so technically skilled.
- Technically demanding devices are places at one point, operation, maintenance and repairs can be ensured at high professional and technical level.
- Condensation heat is conducted beyond upcast airflow stream, outside all workplaces, therefore it has no negative impact on underground workplaces.

Example: Since 2005, section ventilation is in operation in Plant 3 of Darkov Mine (former 9th May

Mine) with cooling output of 2,100 kW, consisting of five cooling aggregates TS-450P/B and six reflux condensers CWW 460/B. Cooling mine airflow is ensured by airflow condensers CP 200/B or CP 250/B from the same producer, the company Termospec from Poland. The ventilators were supplied by the producer of Stalkon type WLE 1004A/1 and 804AM/CZ. The pipelines in all water circuits are designed as groove components Victaulik and with insulation from the producer Hart-Pipe. Cooling water is produced by compressors on the production level by the shaft, from where it is conducted at the temperature of ca. 4-5°C

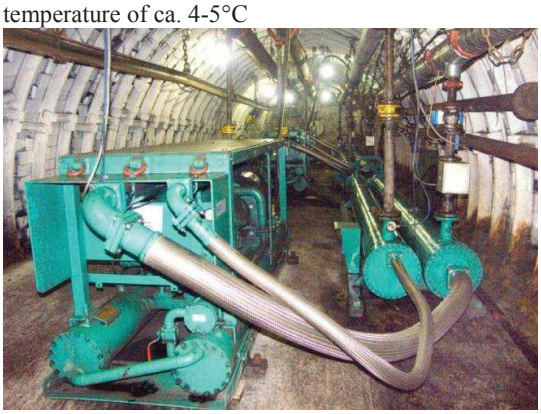

Figure 5 Arrangement of the cooling equipment in mine machine room

Slika 6 *Raspored rashladne opreme u rudničkoj strojarnici*

1.1.4. Central Systems with Surface Cooling

Advantages and disadvantages of this implementation:

- High investment costs.
- Before a decision to install the system is made, it is important to prepare high quality design documentation.
- The equipment installation requires specially built and equipped premises – a chamber for a three-chamber control feeder - SIEMAG.
- Installation requires qualified specialists.
- During the equipment operation there are much fewer breakdowns, because technically demanding devices are stationary at one point and they are not moved.
- Cooling effects are high.
- Condensation heat is conducted outside all workplaces up to the surface.
- It is possible to install high cooling outputs.
- Thermally insulated pipe for coolant inlet.
- Cooling water (coolant) with sufficient ability to transmit cold.
- Sufficiently efficient cooling exchangers with finish that contributes to solving the technology for cleaning the devices from dust deposits lowering their efficiency.

Example: Since 2009, central ventilation is in operation in ČSM - SOUTH Mine (Figure 2) with surface cooling and output of 15 MW. Cooling water is produced in surface hall, from where it is conducted at the temperature of ca. 3°C through pipe of DN 300 diameter (of pressure dimensions of 4 to 16 Mpa) to the chamber located at the level of -806 m. A three-chamber exchanger of the company SIEMAG M-TEC2 is placed in it; it ensures the distribution of cooling water both to the high-pressure primary circuit and to the low-pressure secondary circuit.

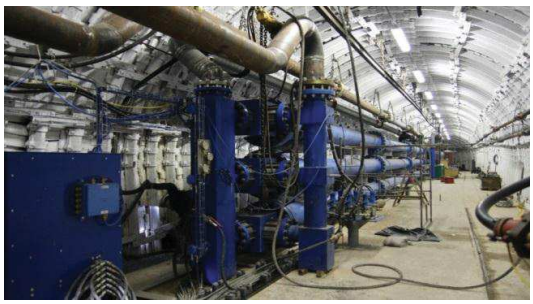

Figure 7 Central ventilation in ČSM – SOUTH Mine

Slika 8 *Središnji sustav provjetravanja u ČSM – rudnik JUŽNI*

The length of pipeline routes of central ventilation with dimensions of DN 300, 250, 150 and 100 after connecting all the condensers of mine airflow exceeds the length of 55 km. The pipe is joined by groove connectors Grinnell, and the cold branch of pipeline routes is insulated. In the final phase, 35 condensers RWK 300 and 8 coal face condensers SPK 35 will be connected to the system; they will cover the demands for cooling output of the whole coal field of ČSM Mine as well as the area of the 5th block in Darkov Mine. If the outside temperature is sufficiently low, the whole system of central ventilation is able to work with higher output – so called "freecooling" (i.e. water in only cooled by the outside air).

1.2. Assessment and Evaluation of Microclimatic Conditions in Workplaces of Ostrava-Karvina Mines

In OKD mines, the microclimatic conditions in workplaces are assessed on the basis of the combination of dry temperature, humid temperature and the speed of airflow. Next, the length of work in mining workplaces is calculated from the tables of so called long-time and short-time permissible time of work. These tables n. 1 to 45 are based on mining workers' energy expenditure (8 categories), relative humidity (9 categories), airflow speed (5 categories) and dry temperature measured in the mining workplace (Law Amendment no. 361/2007

Collection as amended). (Prokop et al. 2013, Zapletal et al. 2012).

Limits are set for acclimatized and non-acclimatized workers. There are two limit values for microclimate permissible on a long-term basis and short-term basis: the "warning one" and the "dangerous one".

Working heat load permissible on a long-term basis is limited by maximum of permissible water loss by perspiration and breathing and by total amount of water loss due to perspiration and breathing per shift. Limit values are set differently, for one thing according to energy intensity of work (M) – for less energy-intense work ($M \leq 80\ W \cdot m^{-2}$) and for work where $M > 80\ W \cdot m^{-2}$, for acclimatized as well as non-acclimatized workers. Workers are considered non-acclimatized for three weeks after the start date in the workplace. Protective beverages are provided when it is proven that workers' water loss during work due to perspiration and breathing is higher than 1.25 per shift (Section 5, Subsection 2 b Law Amendment n. 361/2007 Collection as amended).

Working heat load permissible on a short-term basis is limited for acclimatized and non-acclimatized workers by the amount of heat accumulated in the body, which is $50\,W \cdot m^{-2}$. This value corresponds to the increase in temperature of body core by 0.8 to 1.0 ^{o}C and the increase in heart frequency, depending on the metabolic and climatic load ratio, up to 150 beats. min^{-1}.

Time of work permissible on a long-term and short-term basis is limited by energy expenditure by an average man or woman on a long-term (during an 8-hour shift) and short-term (during a work operation) basis under optimum microclimatic conditions. Under adverse heat and humidity conditions, the stated values are decreased, because heat production of an organism and heat load from the environment are cumulative (Hudecek et al. 2011).

In such cases when time of work permissible on a long-term basis is shorter than the length of shift, a regime of work and rest must be established so that the total time of efficient work per shift does not exceed time of work permissible on a long-term basis (t_{sm}) and the time of uninterrupted work does not exceed time of work permissible on a short-term basis (t_{max}).

The number of work cycles (c) is given by the time of work permissible on a long-term basis and on a short-term basis ratio, while the number of cycles is rounded up to the nearest integer:

$$c = \frac{t_{sm}(min)}{t_{max}(min)}$$

There must be a work break among individual work cycles. At the time of breaks, mine workers must be able to rest in an environment where the temperature of air does not exceed the values stated below:

Table 1 Microclimate required in the Czech Republic

Tablica 2 *Mikroklimatski zahtjevi u Republici Češkoj*

rh (humidity), %	*t_a (dry temperature, °C*
0 - 60	31
61 - 75	30
76 - 90	29
91 - 100	28

Waiting time in connection with coal blasting and meal and rest breaks can be included in break time.

Total efficient working hours per shift determined according to the regulation, compared to the shift efficient working hours determined by the mining company is calculated as the sum of time of work permissible on a long-term basis and the total break time. Comparing the calculated total efficient working hours and shift efficient working hours determined by the mining company may result in more variants, which is solved by the regulation (Law Amendment n. 361/2007 Coll. as amended)

It is forbidden to work in workplaces where the regime of work and rest must be established and conditions of the break regime are not ensured. It also applies to workplaces where t_{max} is shorted than 30 minutes. In tables 1 to 45, this area is coloured with grey.

The provision does not apply to emergency situations when it is imperative to perform work necessary to protect the lives of employees; this work is performed only by the members of Mine Rescue Corps.

2. Microclimatic Conditions in Ukraine Mines in Donbas

Coal mining in Ukraine mines is connected with high temperature of air in mining areas. The temperature of air in mines often exceeds the determined standard that is in compliance with health and safety at work. (see Table 2) (Trofimov et al. 2010).

This table is from Order No. 62 State Committee of Ukraine for Industrial Safety, Labour Protection and Mining Supervision, dated 22.03.2010, The Rules for Safety in Coal Mines (NPAOP - Normatyvno-Pravovyy Akt z Okhorony Pratsi 10.0-1.01-05).

Table. 3 Microclimatic conditions required in Ukraine

Tablica 4 *Mikroklimatski zahtjevi u Ukrajini*

Speed High	*The relative humidity (%)*		
	75% or less	76-90%	90%
	Permissible temperature(°C)		
Up to 0.25	24	23	22
0.26-0,50	25	24	23
0.51-1.00	26	25	24
1.01 or higher	26	26	26

2.1. Mine atmosphere

- Mine atmosphere in composition, temperature and humidity should ensure normal functioning of human during the whole period of stay in the ground.
- The existing mine workings where ever (for changes) are men, temperature and humidity should conform to the standards stated in Table 2.
- If the microclimate differs from permissible values in the workings, a system of measures designed to prevent overheating and chill of employees has to be applied: equipment for air conditioning, construction of special cameras with air conditioning; supply of fresh (chilled) local ventilation air fan in workplaces; the use of personal dust protection (jackets, vests , suits) and others.

2.2. Ways of Cooling

Adverse conditions develop mainly in preparatory workings.

The main source of heat in mines include the coal field, mining machines and transport equipment, mobile electric equipment, coal and mine water. The amount of impact of each of these sources on the temperature of air in mines depends mainly on assembly system, air circuit and ventilation parameters, mine subsidence and other mining parameters.

At the depth of 800-1,300 m, the temperature of air reaches 32-36° C if no measures are taken to decrease it. Such conditions have an adverse impact on miners' health and safety at work, the speed of mining and finally in worsening economic and technical indicators of mines.

In Donbas mines, the temperature of air often increases by up to 10° C. In such case, ensuring normal work conditions in mine is possible only by drawing in air with temperature lower by 10°C. To ensure such heat conditions in Ukraine coal mines, it is necessary to use air ventilation systems with underground stationary cooling units. Air cooling is performed directly in areas of driving of workings using a heat exchanger. Figure 5 shows one of the possible options of this system, consisting of cooling device (1), cooling pipe (2), corridor air cooler (3) and air cooler in blind (driven) workings (4.)

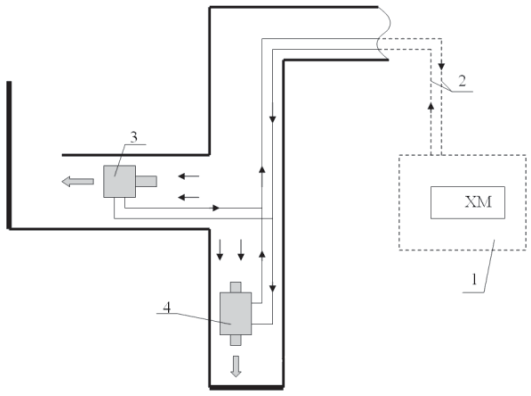

Figure 9 Mine ventilation diagram

Slika 10 *Shema provjetravanja rudnika*

Apart from local air coolers, dispersed supply of cooled (1-2°C) and dried (humidity 2-3 g/kg) air along coalface (e.g. by means of perforated pipeline) is another efficient way to decrease the temperature of air in coalface.

There is another option for the system of ventilation of blind workings mined by means of coal cutter. The coal cutter hydraulics helps to cool the electric motor – air in a discharge air duct and water in the system help to reduce dustiness (see Figure 6). On the whole, this system consists of ventilation pipeline (1), air condenser (2), pipeline for air discharge (3), equipment for cooling the coal cutter engine (4), equipment for cooling the coal cutter hydraulics (5), pipeline for supressing air (6), heat exchangers intended for water cooling systems (7), dedusting unit (8), pipe for drainage (9), the coolant inlet (10). 25% of consumed air is supplied in pipe directly into coalface.

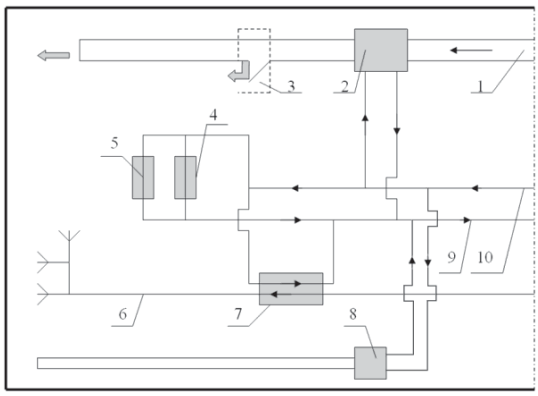

Figure 11 Diagram showing ventilation of blind workings

Slika 12 *Shema separatnog provjetravanja*

3. Conclusions

Introducing mine ventilation is highly dependent on technical possibilities and economic situation of the mine. Before the mine ventilation is introduced, it is necessary to prepare the design of the ventilation and to make the corresponding calculations of mine airflow prognosis using up-to-date computer technology. It is determined to what extent airflow should be cooled in the workplace, or how microclimatic conditions should be adjusted, and on the basis of these calculations the appropriate cooling output is specified.

Decision concerning the way of ventilation of a mining workplace must be based on ventilation costs. This will be affected by the distance of the workplace from the intake, the necessary cooling output, the way of ventilation, the inlet of cooling and return water, the possibility to abandon insulated pipeline due to laying upcast airflow pipeline.

Abbreviations

OKD - "OKD, a.s." is the official name of the company. The primary name was "**O**stravsko-**K**arvimské **D**oly, akciová společnost – Ostrava-Karvina Mines - stock company"

ČSM – JIH is official name of the mine. The primary name was "Důl **Č**esko**S**lovenské **M**ládeže" – The mine of the Czechoslovakian youth"

4. References

Fiurášková, D. (2010): The method of thermal gradient prognosis for rock temperature approximation in conditions of mines in OKD, dissertation, VŠB – TUO, Ostrava

Hudeček, V. et al. (2011): Method of Drilling of Coal Pillar, Journal of Mining Science, Vol.47, No.3, 2011, 82-90

Klanfar, M., Vulin, D., Veinović, Ž. (2010): Assessment of istrian coal bed methane production possibility, Rudarsko Geolosko Naftni Zbornik, Volume 22, Issue 1, Pages 73-80

Prokop, P., Zapletal, P. (2013): Update of directive of ventilation in OKD, Ostrava

Trofimov, V.A., Kavyera, L.A. (2010): Lecture of Aerology mining enterprises, Donetsk National Technical University, Donetsk, 2010

Zapletal, P., Prokop, P., Košňovský, V. (2012): Evolution of microclimatic conditions in Paskov mine, Archives of Mining Sciences, Volume 57, Issue 4, p. 961-971, ISSN 0860-7001

The Rules for Safety in Coal Mines (NPAOP - Normatyvno-Pravovyy Akt z Okhorony Pratsi 10.0-1.01-05)

Law Amendment no. 361/2007 Collection, establishing conditions for the protection of health at work