Arch. Min. Sci., Vol. 57 (2012), No 4, p. 1045–1055

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.2478/v10267-012-0069-3

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EVOLUTION OF MICROCLIMATIC CONDITIONS IN PASKOV MINE

EWOLUCJA WARUNKÓW MIKROKLIMATYCZNYCH W KOPALNI PASKOV

The main subject of this paper focuses on scientific and research activities conducted in the Institute of Mining Engineering and Safety of the VŠB-Technical University of Ostrava. Cooperation between the VŠB-Technical University of Ostrava and OKD A.S., the only representative of coal mining in the Ostrava-Karviná coal basin, has recently begun to develop again. This paper describes an example discussed in a certain study, which has been undertaken for the Paskov mine, OKD a.s., dealing specifically with the evolution of microclimate parameters in mines that depend on the progress of mining activity at deeper levels over a period of several years. To this end, a special program, aimed at determination of the necessary refrigerating capacity, was established at the VŠB-Technical University of Ostrava.

Keywords: mine ventilation, climatic conditions, source of heat, refrigerating unit

W związku ze schodzeniem eksploatacji na większe głębokości i pogarszającymi się warunkami klimatycznymi OKD a.s. wystąpiła do VŠB-TU Ostrava, Wydział Górnictwa i Geologii o opracowanie studium pokazującego zmiany warunków mikroklimatycznych w kopalni Paskov w dwóch punktach czasowych oraz o określenie wymaganej mocy urządzeń chłodniczych. Do tego celu w VŠB-TU w Ostrawie opracowano specjalny program komputerowy określający wymagane moce chłodnicze. Na podstawie studium można podjąć decyzję o ewentualnym zamontowaniu centralnej klimatyzacji dla szybu zastępującej dotychczasowe lokalne jednostki chłodnicze. Studium przeprowadzono zgodnie z rozporządzeniem Czeskiego Urzędu Górnictwa nr 22/1989 w sprawie bezpieczeństwa i higieny pracy oraz bezpieczeństwa przy eksploatacji złóż górniczych oraz przy głębinowym wydobyciu surowców mineralnych, zgodnie z rozporządzeniem Czeskiego Urzędu Górnictwa nr 165/2002 w sprawie odrębnych systemów przewietrzenia w przypadku działalności wydobywczej w kopalniach, w których występuje gaz kopalniany oraz zgodne z rozporządzeniem Rady Ministrów nr 361/2007 w sprawie określenia warunków higieny pracy oraz zgodnie z pozostałymi obowiązującymi przepisami.

Dla przejrzystości obliczeń zmian warunków mikroklimatycznych na wyrobiskach Kopalni Paskov do badań wybrano rejon przyszłego wydobycia – ściany nr 080 210 oraz drążonego wyrobiska nr 080 5255. Omawiany rejon pokładu 080 (dla przyszłej ściany nr 080 210 oraz eksploatowanego wyrobiska nr 080 5255) znajduje się w posieci wentylacyjnej szybu wylotowego nr II/4 (miejscowość Staříč). Wyrobiska zlokalizowano w odrębnym sektorze wentylacyjnym nr 080 210. W poszczególnych

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odcinkach zostały zainstalowane punktowe źródła ciepła (szczegóły w artykule) oraz lokalne urządzenia chłodnicze, co zostało przedstawione na rys. 1.

Przez zainstalowanie klimatyzatorów lokalnych DV 150 w sieci wentylacyjnej w rejonie poddanym badaniu, tzn. w odrębnym sektorze wentylacyjnym nr 080 210, tj. w chodniku nr 080 5253 przed wlotem do wentylatora lutniowego APXK 630 wentylacji odrębnej drążonego chodnika nr 080 5255 oraz w chodniku nr 080 5253 w bliskim przedpolu ściany nr 080 210 doszło do wyraźnej poprawy warunków mikroklimatycznych dla ściany nr 080 210 oraz w jej chodniku wentylacyjnym (z sześciu przerw z powodu pogorszonych warunków mikroklimatycznych bez zainstalowanych klimatyzatorów lokalnych do stanu bez przerwy po zainstalowaniu klimatyzatorów lokalnych), jak również do poprawy warunków mikroklimatycznych na przodku drążonego chodnika nr 080 5255 przy akceptowalnych warunkach mikroklimatycznych w rejonie odprowadzenia strumienia wentylacyjnego z wyrobiska nr 080 5255 posiadającego wentylację odrębną. Przewidywana moc chłodnicza dla rejonu odrębnego sektora wentylacyjnego 080 210 wynosi 300 kW. Badania wskazały na istotną zależność, zgodnie z którą wraz ze wzrostem głębokości wydobycia pogarszają się warunki mikroklimatyczne w miejscu pracy. W przykładzie opisujemy wyrobisko przewidywane na rok 2012, znajdujące się na granicy eksploatacji podpoziomowej. Na tym przykładzie widać, że bez urządzeń chłodniczych nie byłaby możliwa eksploatacja w tym rejonie. W przypadku eksploatacji podpoziomowej warunki mikroklimatyczne w wielu planowanych wyrobiskach osiągały jeszcze gorsze wskaźniki. Z powyższego wynika ważny wniosek, że z punktu widzenia przepisów bezpieczeństwa i higieny pracy nie jest możliwe prowadzenie prac w takich miejscach bez lokalnych urządzeń chłodniczych lub bez centralnego systemu klimatyzacji.

Słowa kluczowe: wentylacja kopalń, warunki klimatyczne, źródło ciepła, urządzenie chłodnicze

1. Introduction

With advances into deeper levels and with aggravating climatic conditions, the VŠB-Technical University (VŠB-TU) of Ostrava, Faculty of Mining and Geology has been asked by the OKD a.s. to prepare a study investigating the evolution of microclimatic conditions in Paskov mine in two temporary cross-sections and to determine the necessary refrigerating output. On the basis of this study, the staff may then decide on the possible implementation of a central air-condition system replacing the mobile air-conditioning units utilized so far. The preparation of the study as well as of this paper has been carried out according to Decree No. 22/1989 Coll. on the Safety and Health Protection and the Safety of Operation in the Mining Industry and the Mining of Non-Reserved Minerals Underground, Decree No. 165/2002 Coll. on Separate Ventilation while Running Mining Operations in Gassy Mines , and the Government Decree No. 361/2007 Coll., determining conditions for occupational health safety at work as well as other provisions in force.

The Paskov mine is a part of the OKD a.s. corporation. Production of hard coking coal of the Va and Vb commercial class was commenced in 1970. An annual output of the mine oscillates around 1,100 kt of coal while the annual advance of mine workings driven in rock for opening up of coal blocks and development workings reaches from 14 to 16 km.

The mining area of Paskov mine is situated in Příbor area of the Czech part of Upper Silesian Coal Basin (beyond the classic Ostrava-Karvina coal area) – figure 1. This mining zone covers an area of 42.51 km^2 and is internally divided into the following locations: Stařič I in Sviadnov, Stařič II in Stařič and Stařič III in Chlebovice.

The mining area of Paskov mine involves the Petřkovice and Hrušov measures of the average thickness of around 70 cm. The average thickness of extracted coal seams is 120 cm., There are shelves of rooted siltstones, sandstones and sandy siltstones in the stone roof overlying the coal seams being mined.

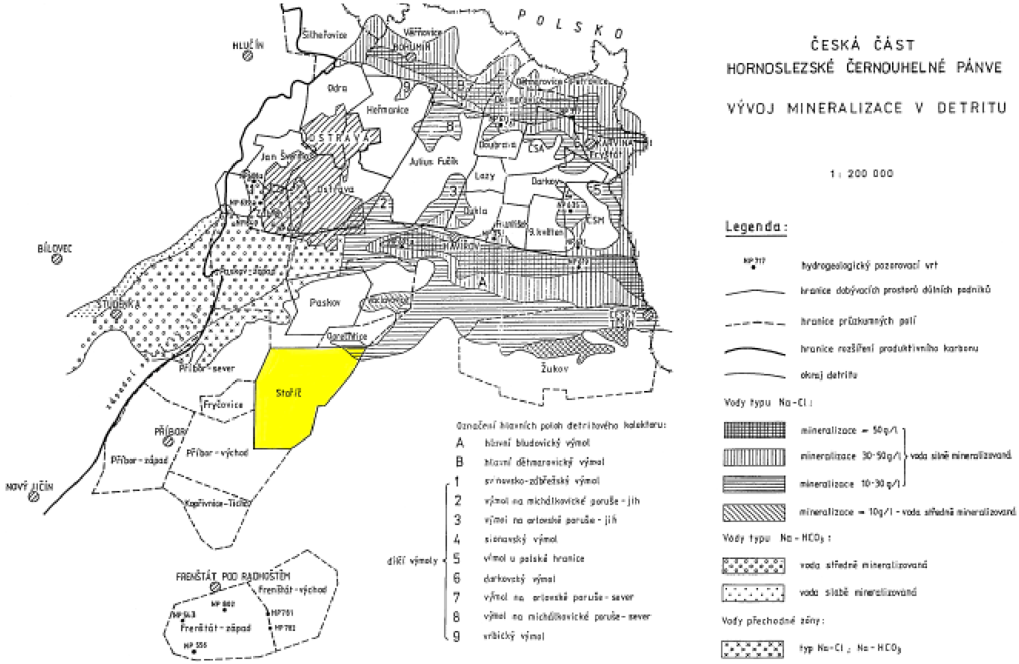

Fig. 1. Localization of the mining area of the Staříč facility of the Paskov mine in the Czech part of the Upper Silesian Black Coal Basin

Currently, the mine extracts coal seam located at the depths ranging from -450 m to even -960 m Bpv, that, is a depth of 750 m to even 1260 m under the surface. The length of mine workings in use is around 127 km.

Coal extraction is performed by means of the directional controlled cave-in longwall mining method with pillar extraction by means of plough systems, and the loosened coal being loaded on scraper conveyors and mined-out area is secured by means of individual hydraulic or powered support. The "U" or "Y" type ventilation systems is applied to provide ventilation of coalface blocks.

1.1. Ventilation system of Paskov mine

The Staříč mining area of Paskov mine is classified to the category of coal-and-gas outbursts susceptible. Mining is carried out with a high degree of gas release (the average gas release fluctuates from 30 to 50 m^3 of CH_4). The efficiency of degasification in the Paskov mine reaches as much as 30%.

The Paskov mine consists of three independent areas with centrally located downcast and upcast shafts and with independent ventilation chambers placed diagonally between areas (between Sviadnov and Staříč ventilation compartments and between Staříč and Chlebovice ventilation compartment).

1.2. Degasification system of the Paskov mine

Degasification system of the Paskov mine is comprised of three degasification stations placed at individual locations with a distribution systems of main and component gas pipelines connected to them. All three degasification stations are connected to the gas pipeline of the central gas administration system, boiler plant installations of individual locations and cogeneration units.

1.3. The current status of machine cooling of workplaces in the Paskov underground mine

Increased application of mechanization in mines and implementation of new technological devices (mining mechanized sets with installed electric motor drives, high-capacity coal removal lines involving belt conveyors, driving complexes, suspended locomotives, etc.) mean an increased demand for electric power supply, as electric energy is used to run these devices. High-power electromotors installed in these technological devices requiring high-capacity transformers, constitute an important source of mine air heating and together with the progress of mining activities into higher depths (increasing temperature of rocks) as well as an increasing concentration of workplaces, they constitute one of the important factors restricting the microclimatic condition prevailing at mine workplaces.

Despite the intense ventilation, the machine cooling is being used in order to improve the microclimatic conditions at individual workplaces (Slazak et al., 2008). As much as 15 mobile air-conditioning units (the DV 150 and MMRP 130 types) are in use in the Paskov mine. Depending on the local conditions prevailing at individual workplaces as well as on the localization of workplaces, these mobile air-conditioning units are either connected to open circulation (with cooling water supply brought from the fire water-line and with the used water drain being led into discharge piping right into septic tank cross-cut placed in terraces of the downcast shaft no. II/4 at Staříč location at the 5th floor level and from there to the main filling station at the surface, or into a closed circuit with the use of reverse coolers (the RK 250, RK 450 and RK600 types) with heat being removed into the upcast (out-flowing) air stream.

1.3.1. Evolution of microclimatic conditions at workplaces in the Paskov mine

Due to the reasons described above, connected with deteriorating microclimate conditions prevailing at mine workplaces, a study entitled as "Evolution of microclimate conditions in the Paskov mine" was elaborated at VŠB-TU of Ostrava in 2011, considering two years of interest – 2012 and 2021. The calculations were processed using the TPCL program, which has been developed by a scientific team of the Institute of Mining Engineering and Safety, under the auspices of OKD a.s. as an ordering party. The TPCL program runs within an AutoCAD software with tabulated and graphical output compatible with MS Excel format.

A wire model of the whole mine or at least of its area of interest is required for work in the TPCL program. When calculating the climatic conditions, computations involve the local heating of mine winds due to, for example, the belt conveyors or plough system drive units, but also heating of mine winds due to their auto-compression (Brudník, 1985), as well as mine winds heating due to contact with surrounding rocks (Taufer et al., 2010), etc. A compressible calculation of ventilation network (Prokop et al., 2010, Zapletal et al., 2011) using an appropriate program is necessary for the work in the TPCL program itself. In our case, the calculation of ventilation network was performed using the Ventgraph program (Dziurzyński et al., 2006, 2009).

The mining area of future coalface no. 080 210 and in the forefield of rock-cut mine working no. 080 5255 were taken in order to illustrate the calculations of the evolution of microclimatic conditions at mine workplaces in the Paskov mine (see fig. 2)

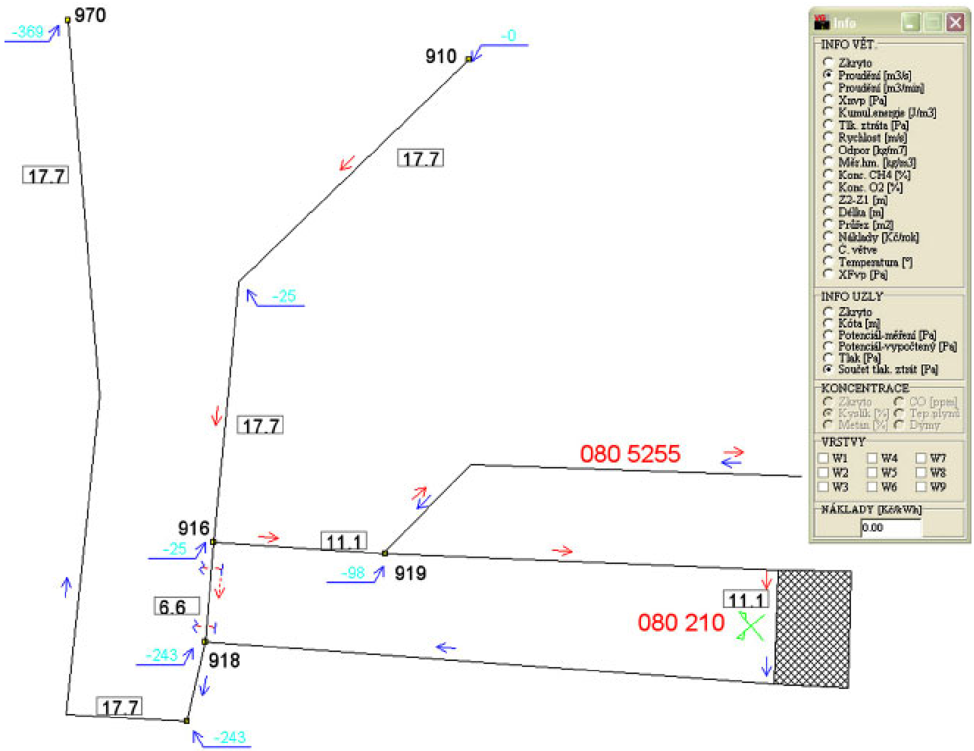

Fig. 2. Ventilation diagram SVO of the coalface no. 080 210 and a working driven in rock no. 080 5255 used for calculations in Ventgraph program

The area of interest of the seam no. 080 (for the purpose of future coalface no. 080 210 and a mine working driven in rock no. 080 5255) is located in a ventilation network in the area of the upcast shaft no. II/4 (the Staříč location). Individual workplaces are placed in the ventilation compartment no. 080 210 itself.

The depth of the area of interest ranges from -825 m to -776 m under the sea level, which is from -1130 m to -1081 m under the surface (the surface spot height of the Paskov mine Staříč location is +305 m).

The working driven in rock no. 080 5255 will serve to mine's subsequent coalface block no. 080 211 and will be used as the mining gangway of the coalface no. 080 211. The drivage of working no. 080 5255 will take place in the forefield from the mine working of the coalface no. 080 210. The working no. 080 5255 will be rock-cut in the K 18-14-18 profile by means of blasting operations using a drill truck DH-DT 1 and a DHL 1200 loading machine with a side loader to a scraper conveyor with a pre-installed crusher. The loosened raw coal will then be transported by a line of belt conveyors into working no. 080 5253, where it will be connected to loosened coal extracted from the coalface no. 080 210. Ventilation of rock-cut working will be taken care of by a separate blow ventilation with the APXK 630 air pipe ventilator and flexible air ducts of 1000 mm in diameter with a volume flow rate of 330 $m^3.min^{-1}$. A power supply train will be installed in the rock-cut working, which will supply electric energy to all drives of boring and conveying machines as well as to technological water pumps.

The coalface no. 080 210 will be extracted in the technology of directionally controlled cave-in longwall mining. The extracted thickness of coal seam is expected to be around 1.0 m, while the daily output of the coalface should be approx. 1000 tons. The coalface will be ventilated using a "U"-system (Berger et al., 2010) with an upward conduction of mine winds with a volume flow rate of 667 $m^3 \cdot min^{-1}$. The length of the coalface block no. 080 210 will an amount of 175 m and expected directional length will an amount of 1300m. Mining will be conducted with the use of the P L730 plough system loading the loosened coal to a working's DH 726 scraper conveyor. The loosened coal will then be conveyed from the coalface's scraper conveyor to collecting crusher-featuring scraper conveyor beneath the coalface of the working no. 080 5253 and further on by a line of belt conveyors via workings no. 080 5253 and 080 7254 to the line of the central belt conveyor transporting the extracted coal (cross-cut no. 2252). Two crushing loaders for processing the working in front of and behind the coalface will be placed at working no. 080 5253 beneath the coalface, while an additional crushing loader will be placed in the outcast working no. 080 5251 in order to process the outcast working. Besides that, a power supply train supplying the electric drives of mining and conveying machines of the coalface and electric drives of the devices in mine working of the coalface together with the hydraulic aggregate will be installed in working no. 080 5253 beneath the coalface.

Installed output of drives of devices supplied by electric energy are:

Working no. 080 7254 and cross-cut working no. 2252 (branch 910-916): (the volume flow rate of 1064 $m^3 \cdot min^{-1}$)

- Drives of the line of belt conveyors 2 × 110 kW
- Input of a transformer 650 kVA

Working no. 080 5253 (branch 916-1008): (the volume flow rate of 667 $m^3 \cdot min^{-1}$)

- The drive of the air duct ventilator 2 × 22 kW
- The pump drive 2 × 30 kW
- Drives of the line of belt conveyors 2 × 110 kW
- Input of transformers 2 × 650 kVA

Rock-cut working no. 080 5255 (branch 1008-1009): (the volume flow rate of 330 $m^3 \cdot min^{-1}$)

- The drive of the drilling truck 1 × 75 kW
- The drive of the scraper conveyor 2 × 250 kW
- The drive of the crusher 1 × 55 kW

- The drive of the side hopper loader 1 × 75 kW
- The pump drive 1 × 30 kW
- Drives of the line of belt conveyors 3 × 150 kW
- Input of the power supply train 400 kVA

Mine working no. 080 5253 (branch 1008-1010): (the volume flow rate of 667 $m^3 \cdot min^{-1}$)

- The drive of the plough system 1 × 100 kW
- The drive of the coalface scraper conveyor 1 × 250 kW
- The drive of collecting scraper conveyor 1 × 250 kW
- The drive of the crusher 1 × 75 kW
- The drive of crushing loaders 3 × 45 kW
- The drive of hydraulic aggregates 1 × 60 kW
- Drives of the line of belt conveyors 2 × 110 kW
- Input of the power supply train 1250 kVA

With respect to the mining technology, there are no drives of any devices run on the electric energy installed in the coalface no. 080 210 (the branch 1011-918, the volume flow rate of 667 $m^3 \cdot min^{-1}$).
Upcast working no. 080 5251 (the branch 1011-918): (the volume flow rate of 667 $m^3 \cdot min^{-1}$)

- The drive of the plough system 1 × 100 kW
- The drive of the coalface scraper conveyor 1 × 250 kW
- The drive of crushing loader 1 × 45 kW

The short-circuit no. 080 7254 (branch 916-918): (the volume flow rate of 397 $m^3 \cdot min^{-1}$)

- The drive of the air duct ventilator 1 × 22 kW

For the purpose of computations, an excessive average annual temperature was selected at the entrance to the coal seam no. 080 (at the beginning of the independent ventilation compartment no. 080 210) at the crossroads of the cross-cut working no. 2252 with the working no. 084.5257/1: dry temperature T_s = 25.1°C, wet temperature T_s = 18.6°C, relative air humidity 54%.

1.4. Calculation of parameters without cooling units

After all necessary initial values were fed into the TPCL computational program (the first computation was conducted without considering the DV 150 mobile air-conditioning devices), the following values were obtained:

1.4.1. Rock-cut working no. 080 5255

The face of rock-cut working no. 080 5255

Dry temperature T_s = 30.0°C wet temperature T_s = 23.7°C relative air humidity 59%

According to the "Internal provision for evaluation of microclimatic conditions and determination of permissible work-time in OKD mines" (Ostrava 2003, 2004), which is an integral part of the Government Regulation No. 361/2007 Coll. issued on December 12, 2007, determining the conditions for occupational health protection, in the wording of subsequent provisions, these values imply for the work class of energy expenditure of EV-III. (150-169 $W \cdot m^{-2}$) – hereinafter only referred to as EV-III – the following factors are:

- long-term tolerable work time t_{sm} = 448 min.
- transiently tolerable work time t_{sm} = 448 min.

At the face of rock-cut working no. 080 5255, the regime of work and rest at workplace does not need to be necessarily specified (without interrupting the work due to aggravated microclimate conditions by a minimum pause of 30 min.)

Outlet of separately ventilated rock-cut working no. 080 5255

Dry temperature T_s = 33.6°C wet temperature T_s = 28.4°C relative air humidity 68%

The calculations indicate aggravated microclimatic conditions in the outlet segment of upcast air stream running from the separately ventilated working no. 080 5255.

1.4.2. Coalface no. 080 210

Dry temperature T_s = 34.7°C wet temperature T_s = 29.6°C relative air humidity 68%

Bottom dead center of the coalface no. 080 210

Dry temperature T_s = 33.5°C wet temperature T_s = 27.6°C relative air humidity 63%

Top dead center of the coalface no. 080 210

Dry temperature T_s = 35.8°C wet temperature T_s = 31.6°C relative air humidity 74%

<u>What implies for the EV-III class work:</u>

- long-term tolerable work time t_{sm} = 278 min.
- transiently tolerable work time t_{sm} = 46 min.

In the case of the coalface no. 080 210, the work and rest regime at the workplace must be specified (with 6 pauses in work due to aggravated microclimate conditions, with a work pause at the minimal length of 30 min.).

Upcast working no. 080 5251 from the coalface no. 080 210

Dry temperature T_s = 37.5°C wet temperature T_s = 34.5°C relative air humidity 81%

The calculations indicate very bad microclimate conditions in upcast working from the coalface no. 080 210. – see fig. 3

1.5. Calculation of parameters with air-conditioning units

For the purpose of subsequent calculations in TPCL program, the values after involving two DV 150 air-conditioning units were input (with the refrigeration output of 150 kW), and specifically:

1. For the working no. 080 5253 in front of the inlet of APXK 630 air pipe ventilator of separate ventilation of rock-cut working no. 080 5255.
2. For the working no. 080 5253 (mine working) in close forefield of the coalface no. 080 210

The following values were obtained based on calculations:

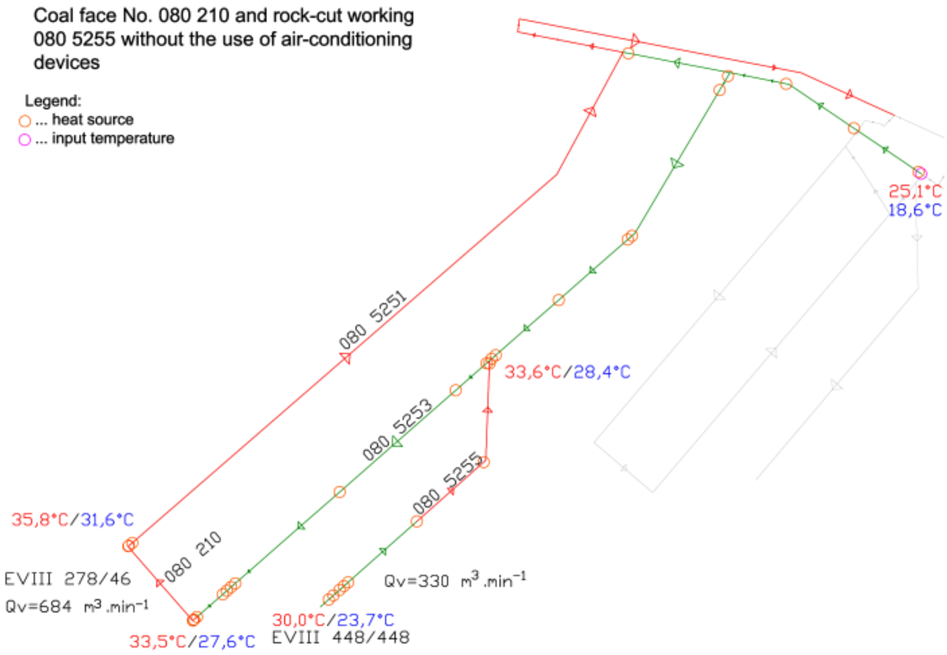

Fig. 3. Schematic diagram of calculation of expected temperatures at the workplaces of interest without the use of air-conditioning devices

1.5.1. Rock-cut working no. 080 5255

The face of rock-cut working no. 080 5255

Dry temperature T_s = 25.6°C wet temperature T_s = 19.7°C relative air humidity 57%

<u>What implies for the EV-III class work:</u>

- long-term tolerable work-time t_{sm} = 480 min.
- transiently tolerable work-time t_{sm} = 480 min.

At the face of rock-cut working no. 080 5255, the regime of work and rest at workplace does not need to be necessarily specified (without interrupting the work due to aggravated microclimate conditions by a minimum pause of 30 min.)

Outlet of separately ventilated rock-cut working no. 080 5255

Dry temperature T_s = 29.8°C wet temperature T_s = 24.7°C relative air humidity 65%

The calculations indicate acceptable microclimatic conditions in the segment of upcast air stream from separately ventilated working no. 080 5255.

1.5.2. Coalface no. 080 210

Dry temperature T_s = 26.7°C wet temperature T_s = 21.9°C relative air humidity 65%

Bottom dead center of the coalface no. 080 210

Dry temperature T_s = 24.2°C wet temperature T_s = 19,2°C relative air humidity 62%

Top dead center of the coalface no. 080 210

Dry temperature T_s = 29.2°C wet temperature T_s = 24.6°C relative air humidity 68%

What implies for the EV-III class work:

- long-term tolerable work-time t_{sm} = 480 min.
- transiently tolerable work-time t_{sm} = 480 min.

In the case of the coalface no. 080 210, the work and rest regime at the workplace does not need to be necessarily specified (without interrupting the work due to aggravated microclimate conditions by a minimum pause of 30 min.).

Upcast working no. 080 5251 from the coalface no. 080 210

Dry temperature T_s = 31.6°C wet temperature T_s = 28.1°C relative air humidity 77%

The calculations indicate acceptable microclimatic conditions in the upcast working from the coalface no. 080 210. Only at its very end, the microclimate conditions undergo slight aggravation (see fig. 4).

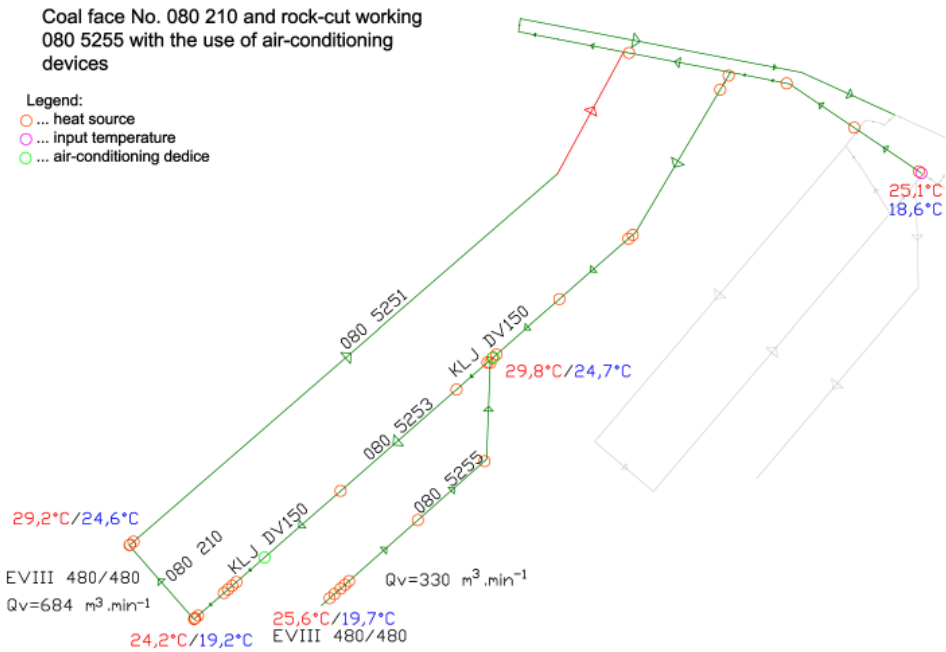

Fig. 4. Schematic diagram of calculation of expected temperatures at the workplaces of interest with the use of air-conditioning units

Conclusion

Involvement of the DV 150 mobile air-conditioning units into a ventilation network of the area of interest on independent ventilation compartment no. 080 210, that is in working no. 5253 just in front of the inlet of the APXK 630 air-duct fan of the separate ventilation system of rock-cut working no. 080 5255 and on gallery no. 080 5253 in the close forefield of the coalface no. 080 210, resulted in considerable improvement of microclimate conditions at coalface no. 080 210 and in its upcast working (conditions have changed from 6 interruptions due to aggravated microclimatic conditions when the mobile air-conditioning units were not in use in a state without any necessary interruption following the involvement of mobile air-conditioning units) and in improvement of microclimate conditions at the face of rock-cut working no. 080 5255 with acceptable microclimate conditions at the outlet part of upcast air stream from the separately ventilated working no. 080 5255.

Refrigerating output required for the area of independently ventilated compartment no. 080 210 should be expected to be approx. 300 kW.

This study clearly demonstrated an important fact that the microclimatic conditions at workplaces aggravate with increasing depths. In this case, we consider a hypothetical workplace in 2012, which is located at the edge of under-level mining area. Even at this level, it is already obvious that this workplace could not be run without the use of air-conditioning units. In the case of under-level mining, the microclimatic conditions get even worse at many workplaces. An important conclusion, which results from these observations, is that from the point of view of work safety, it is not possible to run such workplaces without the use of mobile air-conditioning units or the central air-conditioning system.

This paper was prepared when solving the project ***105/09/0275, Solving the safety risks accompanying the working under the main haulage level in OKR,*** under the financial support of the GACR.

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Received: 28 December 2011