Türkiye 15Madencilik Kongresi /*15"" Mining Congress of Turkey,* Güyagüler,Ersayın,Bi]gen(eds)(P 1997, ISBN 975-395-216-3

VENTILATION AND AIR-CONDITIONING DURING OPERATION IN DEEP MINES - A FOREMOST ENGINEERING TASK

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ABSTRACT: Mining operations in the Mieden Rid mine are earned out in specific ventilation-climatic conditions. The rock temperature below 1000 m from the Earth's surface is about 40-45° C, the relative humidity of the air in the workings is approx. 80-90%. The equivalent orifice of the mine is A < 1 m^2. The difficulty for additional fresh air supply will complicate the ventilation-conditioning conditions both to the mining blocks and to the mine as a whole. The authors have based their engineering designs on the methods and computer software for mine ventilation networks design used in Bulgaria. Alternative schemes for max. supply of fresh ventilation stream to the working, minimizing the spent stream recirculation through conventional mining-service means and fans for general and local ventilation are described. Heat and ventilation calculations are made for determination of the temperature of the ventilating streams in the workings, pipings and face spaces during mining up to 1200 m in depth in order to be determined the necessity of man-made cooling of the air. On the basis of the obtained results the required refrigerating capacity is determined for the individual jjyorkihgs and are recommended small-size portable air-coolers for improvement of the thermal conditions for the miners on their working.

1 INTRODUCTION

The underground mining in Bulgaria is characterized with intensive development and deepening of mining operations. The temperature of the rock massif is expected to be 50-60°C, which will result İn increasing the temperature of mine atmosphere and will exert unfavourable effect on the health and productivity of miners.

Deeper penetration of mining operations in some of the underground mines of GORUBSO Co. and BOURGAS COPPER MINES Co. has brought to increasing the number of work places with unfavourable climatic conditions because of the high rock temperature and humidity of air.

During the opening of deep level floors in the region of Erma river were crossed rocks with temperature over 70°C. The géothermie gradient in this region varies from 4 to n.lO'^C/m.

This is due to the presence of geothermal anomaly, caused by the additional heating of the rock massif by thermal karst water with temperature from 80 to 100 "C. (Niproruda, 1987). Currently the temperature of the rock of the operetine mines reaches to 30-SfVC

The complicated climate conditions at the working areas made necessary the following mining-engineering tasks to be solved

- determination of the required and sufficient amount of air by temperature factor for the systems applied for mining at the current stage and in depth.

- forecasting the maximum depth that mining operation could be run without using means for cooling of the air.

- estimation of the required cooling capacities at the present stage and in the future in order to provide an admissible microclimate at the working places.

The Meden Rid mine started its production more, than 50 years ago. The initial geological surveys of the ore field presented evidence which allowed to open up the vein deposit by two central shafts (Fig. 1) with the perspective of developing the mining operations down to 500-600m below the surface under comparatively favourable aerological conditions. Shafts 1 and 2 have rectangular sections of 9 0 and 9.5 m^2, respectively. The fast advance of the mine in depth under fairly good miring and economic conditions necessitated an increase in the development depth by blind shafts 3 and 4 which have the transportation and air transfer capacity of the first two shafts. Thus levels 950 and 1000 were reached with proven mining reserves down to level 1200.

The mine shaped m the manner described above (Fig. 1) is characterized by a geothermal gradient of 37.8 m/°C, siliceous dust and higher radioactivity of the rock mass. The method of mining the ore veins is sublevel caving. The stopes are ventilated by auxiliary fans. The goaf above level 950 is caved. At every 40-50 m between the shafts there are cross-cuts as well as connections with the goaf. Isolating seals have been built for channelling the inlet and outlet air currents in accordance with the operation of the BOKD-1 5 and BHCB-16-type main fans.

The mine ventilation scheme which has been operating since the beginning of 1996 is shown in the figure. The ventilation of working levels 950 and 1000 has been evaluated as unsatisfactory. A design has been worked out for improving the main ventilating system and the microclimate at the work places in two variants: first variant - two stopes at level 1000 and two heading faces at level 1050, second variant - two stopes at level 1000 and three stopes at level 1050 with perspectives for the development of mining operations down to level 1200. The rock temperature at level 1000 is 39,7°C and at level 1200 it reaches to 46.1°C.

2 A NUMERICAL MODEL OF THE MINE VENTILATION SYSTEM

The complex aerodynamic and thermophysical processes in the mine ventilation networks are quite fully described by the software packages VENT-2 and VENT-4 (Stefanov, 1986). The accuracy of the calculations depends mainly on the prescribed input data, i.e. aerodynamic drags, sources of air draught and thermophysical coefficients The following practical problems can be solved by an adequate numerical model of the operating mine ventilation

- evaluating the regulating capacity of the ventilation system;
- designing the development of the system,
- selecting the fans and air coolers;

The real numerical data needed for solving the problems have been obtained by direct measurements in the mine The number and location of the measuring stations have been chosen by metrological and topological criteria for reaching reliability of the result and for completing the antilree of the ventilation network scheme with a preliminary data base (Stefanov, 1986). On this basis multiple calculations have been made of the air distribution in the network and the admissible difference between the measured and calculated volumetric flows has been determined (Table 1). The following criteria for adequacy of the numerical model of the ventilation system have been assumed calculation errors up to 20% of the measured air quantities in the network splits of the 1, II and III rank, as well as in the ventilated sites (stopes and heading faces). The method chosen and the criteria are difficult to apply without compromises of mainly topological character All volumetric flows have been reduced to an air density of 1 2 kg/m .

3.ANALYSIS OF THE OPERATING VENTILATION SYSTEM

A quantitative ventilation survey was carried out to determine the operating mode of the main fans and their performance. For the purpose, the static • pressures were measured in sections in front of and behind the ventilation units installed on level 550 and level 850. The two fans operate in series. The results obtained are as follows.

For the axial-flow fan on level 550:
-air quantity 38.52 m^3/s
-pressure 2100 Pa

For the centrifugal fan on level 850
- air quantity 34.1 m^3/s
-pressure 1390 Pa

The measured parameters were introduced as input data in the approximation of the mine ventilation network The analysis of the air distribution along the main airways (Table 1) shows that 10.2 m^3/s of fresh • air is supplied to the mine and 36.3 m^3/s of air passes through the main ventilation unit on level 550. This means that 28% of the air moving along the ventilation network is fresh and the remaining 72% is recalculation air The analysis of the pressure losses for the whole mine shows that 37.7% of the total loss in the main intake and return airways comes from shaft 4 Therefore it is the bottleneck of the mine from a ventilation point of view. In general, the mine is difficult to ventilate - its equivalent orifice is $A=0.6546\ m^3$.

On level 1000, in sinking a rise at a height of 10 m from the heading in a blasthole 42 mm dia , 10 - 12 mm from the opening of the hole and after intensive ventilation of the nse face for 7 h, a rock tempeialure of 34 3°C was measured This shows thai the expected primary rock temperature on level 1000

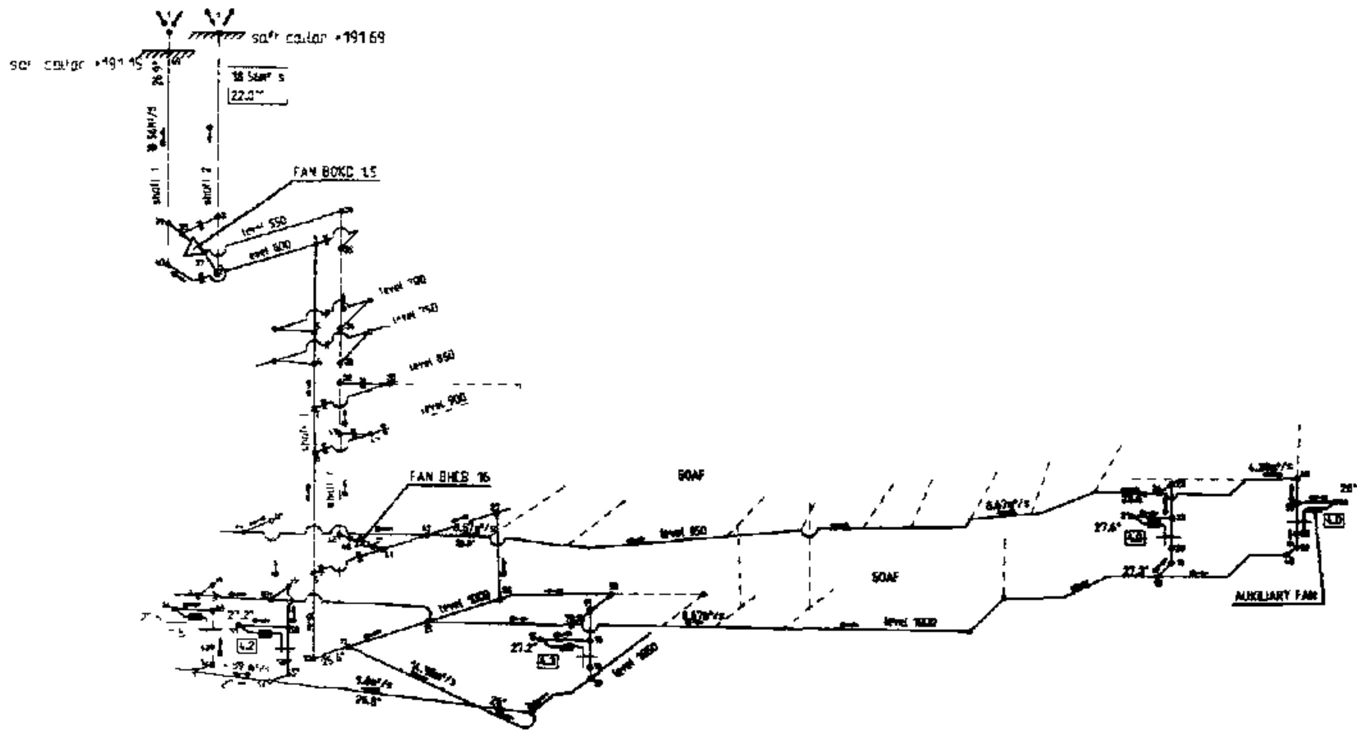

Fig.1. Ventilation plan of the mine

according to the géothermie degree is 39 7°C.The dry-bulb temperature of the air in the face area was td= 30.1°C and the wet-bulb temperature tw = 30.0°C, and the relative air moisture content (p = 98%.

For estimating the capacity of the airways and the operation of the main ventilation installations, the air distribution and- the pressure losses along the workings were calculated by using the software package VENT-2. Since the Meden Rid mine is radioactive, the necessary quantity of air for ventilating the working places was determined by the formula (Ministry of Public Health, 1982):

$$Q_r = Q.(1.23.E + 051), m^3/s \quad (1)$$

where: Q,, - necessary quantity of air for ventilating blind workings by radiation factor, m^3/s; Q, - supplied quantity of air for ventilating the working place, m^3/s, E - concealed energy measured in units x lO'/Mev.

Table 1 shows the real air quantity supplied to the working places, measured during the tests and the calculated air quantity necessary to ventilate the same working places.

Table 1 - Measured and calculated volumetric flows

No. of columns	No. of junctions	Type of working	Volumetric flow, m^3/sec	
	$J_{ini} - J_{fin}$		Measured	Calculated
		I. INLET FLOWS		
1	1-237	Shaft 2 - collar	11.1	10.7
4	4-5	Shaft 2 - level 600		15.0
5	5-6	Crosscut level 600	27.8	20.7
6	6-7	Shaft 3 - level 600	23.8	16.1
11	11-12	Level 1000	8.4	8.2
82	11-139	Level 950	9.1	10.9
255	238-237	Old vent.inst.at air rise	0.5	0.6
		II. OUTLET FLOWS		
33	27-28	Level 850 - vent.inst.	34.8	33.6
36	33-34	Shaft 4 - level 550	-	36.2
37	34-35	Level 550 - vent.inst.	39.4	36.3
39	36-37	Shaft 1 - level 550	43.9	23.6
41	236-1	Shaft 1 - collar	-	11
		III. WORKING PLACES		
127	91-111	Block 959	3.26	6.81
136	84-94	Block 961	2.78	4.90
91	64-65	Block 1000	2.00	4.20
14	13-14	Block 1002	1.80	2.70
103	74-121	Block 969	1.37	3.10
159	88-117	Block 967	3.26	4.40
67	53-54	Rise - level 1000	3.70	4.30

As a result of the analysis and evaluation of the present condition of the mine ventilation network, the ventilation output and capacity of the airways, the following conclusions were made:

a) the present central mine ventilation scheme creates conditions for higher losses of air,

b) the unsealed connections between the main intake and return airways are the main cause of the considerable air losses;.

c) The location of the main fans also causes the air leakage to turn into recirculation currents;

d) The unchanneled polluted airflow creates conditions for an increase in the air temperature and radioactivity in the mine when the development and extraction mining operations go down below level 1000

The decrease in air losses and the reducing of the airflow recirculation to a minimum for the existing development workings are only possible if

- the connections of the shafts to the old mined-out upper levels are isolated.

- the main fan, located until now on level 850, is moved to a new place,
- the ventilation level is, maintained and the air is withdrawn along the flanks ofthat level
- the retreat method of mining is compulsory under level 1000

4 SOLUTIONS FOR IMPROVEMENT AND DEVELOPMENT OF THE MrNE VENTILATION

The adequate numerical model of the operating ventilation system designed by the authors is used for predicting the mine air temperatures and for developing projects for improving the ventilation on level 1000 and its development down to level 1200 For this purpose software packages VENT-2 and VENT-KL (Dimitrov, 1986) were used By multivanant calculations it was sought to find a way to decrease the air losses and recirculation in the shafts, to determine the location and output of the fans and air coolers

In the variants discussed the BOKD-1 5-type fan remains on level 550 but the second BHCB-16-type main fan is moved and installed on level 950 Levels 1000 to 1200 will be developed by inclined drifts (inclines) The polluted airflow is channelled *on* level 950 The necessary air quantities for the working places are prescribed as superimposed flowrates for the stopes - 4 0 - 4 3 m^3/s at a rate of 0 7 m/s and for the heading faces - 6 5 m^3/s at a rate of 0 95 m/s (Fig 1)

Thus the following results were obtained For the BOKD-1 5-type tan on level 550
- output, m^3/s - I variant - 20 69
  - IIvariant- 21 25
- pressure. Pa - I variant - 2656 4
  - II variant - 2672 5

For the BHCB16-type fan on level 9S0
- output, mVs - I variant - 23 67
  - II variant - 24 88
- pressure Pa - I variant - 28T7 5
  - II \auant 2705 5

Foi the variant discussed with three stopes on level 1200 the partial operating modes of the main fans, aie as follows for the BOKD-1 5-type - output 21 16 mVs, pressure 2670 I Pa, for the BHCB-16-lype - output 26 84 and pressure 2710 4 Pa

The analysis of the results obtained showed that 74-76% or the inlet air is fresh and only 24-26% is recirculation air Hence the conclusions fiom the tests were correct in spite of the remaining difficulty of ventilating the mine

The aim t f the thermophysical calculations was to determine the airflow temperatures m the workings, air ducts and face areas in view of defining the need for artificial air cooling and the cooling range

For each branch of the network we have introduced the following input data

M - type of the working (dry, M=0)
τ - time of existing of the working (million seconds)
λ - rock heat conductivity, w/m°C
c_p - specific heat capacity of the rock, J/kg°C
ρ - rock density, kg/m^J
ξ -coefiicient of unevenness of the workings, (1 to 3)
D – equivalent diameter, m
F_l - specific humidity of the air, %
Q_α* - specific heat of oxidation, w/m
θ - primary rock temperature, °C

The necessary refrigeration output of the aggregated air coolers in the respective working places $\Delta \Phi t$ was determined by the formula (Stefanov, 1986)

$$\Delta \Phi t = r \, Q \, C_p \, Dt_{cool} \;\; kw \tag{2}$$

where r - standard air density, kg/m\ Q - volumetric flow *of* cooled air *m*/s,* C_p - specific heat *of* air, J/kgK, Δt_{cool} - cooling range, °C

In the model of the ventilation network a superimposed temperature t, = 25°C was assigned for every working place and every point

$$t_s = t - Dt_{cool}, \; °C \tag{3}$$

where t - temperature at the respective point before cooling, °C

The calculations for determining the necessary refrigeration output were carried out at average day temperatures for the summer and transitional periods i'U)°C 15 0°C 16 0°C, 18 0°C, 20 0°C, 24 0T ana 26 0°C It was found that a necessity for artificial 3» cooling arises at an inlet air temperature higher than I8 0°C

thus the following lesults were obtained for level 1000 the necessary refrigeration output for the stopes is between 4 3 - 20 kw

For level 1050 when driving development workings the necessary refrigeration output of the air coolers is between 10 - SO kw and 4 0 - 21 8 kw for the stopes, having already established the conncUion with the ventilation level

I oi level 1200 the necessary output of the air coolers for the slopes is between 6 S - "Î2 0 kw

5.C0NCLUSI0N BASED ON THE RESULTS OBTAINED FROM THE VENTILATION-COOLING CALCULATIONS

The analysis of the results obtained from the ventilation-cooling calculations dunng mining operations on level 1000, level 1050 and level 1200 in the Meden Rid mine allows to make the following conclusions.

a) Despite the maximum allowable cutüng off from the ventilation scheme of old worked-out areas, the mine is still difficult to ventilate.

b) The recirculation of mine air can be reduced from 72% to approximately 24%.

c) The installation of a second main fan from level 850 to level 950 and the channelling of the inlet and outlet airflows create conditions for a more economic operating regime of the main fans and less energy consumption

d) At an inlet air temperature of up to 18°C it is not necessary to cool the air at the working places

Undoubtedly, when dnving the development workings, higher refrigeration output will be necessary until a connection is made with the higher levels.

6 CONCLUSIONS

The production activities in the Meden Rid mine under conditions of development and extraction operations earned out below level 1000 are possible only if the airflow along the shafts and the ventilation level 950 is properly channelled, the main fan from level 850 is moved down to level 950 and aircoolers are used for conditioning the inlet airflow to the development blind workings and slopes on level 1000, level 1050 and level 1200

It is expedient to be used the small-size cooling facilities and air conditioners of lower unit capacity, installed near to/or just in the working areas Such an appro;!! h combined with an intensified ventilation will resuli m lolally lower mine power for cooling purposes

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