LOCAL VENTILATION SYSTEM'S CONTROL

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ABSTRACT. In the construction and operation of dead-end underground objects local ventilation systems are applied. They diluted liberated waste products and transferred them outside the place. In order to ensure proper ventilation of these objects operation of the system has to be periodically controlled and tested. It includes control measurements of working environment, inspections and control measures and efficiency of auxiliary ventilation. The paper presents whole measurement cycle: inspection of installation, measuring devices, logics in consequence of measurements, results monitoring. Important part of control process is local fan's parameters. Illustration is made on an example of forcing system for local ventilation.

Key words: mine ventilation, local ventilation, control, inspection, auxiliary ventilation, auxiliary fans

КОНТРОЛ НА СИСТЕМИ ЗА МЕСТНО ПРОВЕТРЯВАНЕ

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РЕЗЮМЕ. При строежа и експлоатацията на глухи минни изработки за осигуряването на проветряването се използват системи за местна вентилация, които разреждат и изнасят отделените вредности извън тези изработки. За правилното проветряване на изработките и експлоатация на тези системи е необходимо да се извършват периодични проверки и контролни измервания за установяване на режима на проветряване на изработките и ефективността на работа на системите за местна вентилация. В статията са представени методи и необходими уреди за провеждане на контролни измервания при местни вентилационни системи, както и форми за проверка и мониторинг на тези системи. Даден е пример за контрол и мониторинг на нагнетателна система за местно проветряване..

Ключови думи: местно проветряване, минна вентилация, контрол, инспектиране, вентилатори за местно проветряване;

Introduction

Underground facilities at their initial construction phase pass through configuration when fresh and exhaust ventilation air flow/outflow from the same location – dead end pathways. These group include road, railway and metro tunnels, underground parkways and garages, mine workings in development stage. For most of the above mentioned objects these configurations are only temporarily, but still different work phases in their development and exploitation exist while in a real operational process other types of ventilation are applied. In underground mines however such objects – dead end roadways with local ventilation systems operate in the whole work cycle of the mine, being a part of the overall production process. What is more – they remain part of mine ventilation system, influencing at the great extent its efficient work.

This paper presents author's experience in design and control of local ventilation system. Special attention is drawn upon consequence in control operations, methods and means for effectiveness achievement in two directions – ensuring safety work conditions with minimal expenses for ventilation.

Generally used systems for local ventilation

As stated above with application of local ventilation systems normal and safety atmosphere in a face should be guarantee. It serve also to export exhaust air outside the premises according to safety regulations. Since varieties in work conditions exists, different systems for local ventilation are applied. They incorporate exhaust fans and specially constructed pipelines to supply fresh air and to extract exhaust air. Fig. 1 presents one dead end roadway, ventilated by a forced fan, located outside the place. Fan supplies fresh air at the face, diluted the harmful impurities, emitted during the work process Exhaust air is extracted parallel to the pipeline along the length of roadway. Following symbols are marked on fig. 1:

Qv – air flow through the fan, m³/s,
Qa – air flow of main current, m³/s,
Qo – air flow, supplied to the face, m³/s,
Lf – length of face, m.

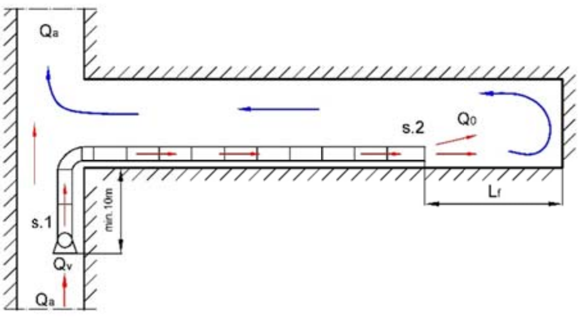

Fig. 1. Forced local ventilation system

Varieties in local ventilation schemes, applied most widely, can be summarized in the following three groups:

- forcing or blowing system for ventilation (fig.1.);
- exhausting system (reversed flow compared to fig.1. – the fan extracts flow from the face and operated at exhaust regime);
- systems with overlaps (fig.2 shows exhausting system with force overlap). Similar scheme can be realized in other way - forcing system with exhaust overlap.

Advantages and disadvantages of the above presented systems for local ventilation are discussed widely and thoroughly in McPherson, 1993 and in Stefanov,1991. Forced systems, due to their advantages, not complicated design and realization, are most widely applied and utilized in practice. By that reason further in the paper given examples are with forced system.

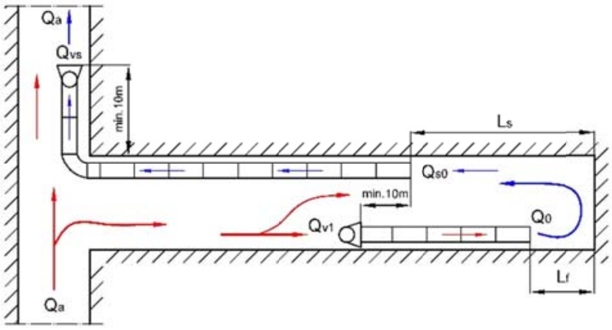

Fig.2. Exhausting system with force overlap

In a big mine during the whole life cycle of the enterprise simultaneously operate several local ventilation systems, together with main ventilation system. Work, requiring local ventilation, include construction of developing workings, chimneys and other facilities. Summing up costs for local ventilation they might equalize or even exceed power of main fans. That is one real reason to control and optimize local systems performance. When these systems are not limited in number, the amount of measurements and regulations increases rapidly in order to maintain ventilation systems in their effective range, closed to the design documentations.

Requirements for local systems control

Control of different systems in a mine, including local and main ventilation systems, is performed upon underground mining regulations (Pravilnik 1992, Pravilnik 1971). As regards to ventilation systems, regulations are restricted mainly to safety requirements (not to technical performance) for main fans and installation. Local ventilation and control of its parameters is discussed in Kertikov, 1996. Again, main attention is drawn upon health and safety work environment factors and their values, rather than clear rules for their achievement.

Passages and texts from BG mine regulations, applied for local ventilation, can be summarized as follows:

- ventilation only by diffusion in a non-gassy mines is restricted to 10m for horizontal pathways and 5m for vertical ones;
- one dead-end facility should be ventilated by its own independent local ventilation system, supplied with fresh air either from the surface or from air flow, delivered by main fan;
- local ventilation systems work uninterruptedly;
- no air recirculation from exhaust flow towards supply one is permitted;
- air recirculation is prevented by the following technical measures: local fan (forced or exhaust) is mounted at least 10 m away from the mouth of dead-end underground workings and 15 m away from ones, having outcome to the surface;
- local fan air flow, supplied to its sucking opening, is restricted to up to 70% of main current flow;
- air flow velocity in developing mine workings is limited into range 0,15 - 4m/s;
- all measurements for ventilation system's performance should be registered in ventilation journal.

Consistent policy for mine ventilation management can bring positive outcomes in several directions – efficiency increase, decrease in electricity consumption but in the same time – ensuring safety work conditions. As stated in De Souza, 2017 establishment of mine ventilation management program, which include local ventilation, will create a basis for achievement of the above given three benefits – effectiveness, costs and safety. Such management program cover purpose, design, measurements and control, analysis, corrections and improvements. This paper is concentrated on measurements and control, without neglecting the other parts of the program.

Local ventilation system's examination

Design of local ventilation system is made by qualified ventilation engineer. The project is then transformed on a real object, as closed as possible to calculations and instructions. Further, maintenance is very important task, which has to be done according to safety regulations, meeting "best practice". In brief – construction of local ventilation system adequate to the project and maintenance in phases, described in it.

All the above mentioned steps in initiation and effective work of local ventilation system, require creation of plan for management, as a part of general management of the whole ventilation in a mine. Such plan include detail examinations of all system's components, air flow and pressure measurements, concentration of contaminants in work environment as well as other parameters, required by safety regulations.

Local ventilation checks should be performed regularly – once for every 24 hours and after increase in length or other change of pipeline. Obtained results is recommended to write and saved into special journal with specially created positions, questions and information. These data should is enough to show ventilation installation's operation status. One example of such check list is presented in table 1. Proposed table is a model and can vary in accordance with type, amount and purpose of ventilation installation and work place of its service.

Table 1.
Examination and control form

Date and time: *10:20*	**Work shift:** *1*	
Work place: *7th gallery*	**Section:** *II*	
Required air flow, m^3/s: *6.5m^3/s*		
Fan No: *2BM*		
Distance from face to end of pipeline: *12m*		
Gas concentrations:		
Gas	**measured**	**regulation**
Oxygen –O_2, %	*20.3*	**> 20**
Carbon monoxide – CO, ppm	*14*	**32**
Carbon oxide –CO_2 ,%	*0.08*	**0.5**
Nitrogen monoxide – NO ,ppm	*4*	**15**
Nitrogen oxide – NO_2, ppm	*0.5*	**2**
Other: ______________		

Check list:	
Parameter	
Fan is correctly mounted and fixed	
Fan's outlet is supplied with safety grid	
Fan has silencer	
Fan's location is at least 10 m away from the mouth of mine working in air flow direction	
Connection between pipeline and fan is correct	
Are there damaged parts of pipeline?	
Is the pipeline safety hanged?	**X**
Pipeline sectors are properly linked	
Pipeline axis is horizontal and strait	**X**
What type of connection between different pipeline diameter and fan's outlet are used and are they properly mounted?	
Is the distance between pipeline end and face is within 20-25 m?	
Gas concentrations are according to regulations	
Required air flow is supplied to the face	
Comment: *Hang safety the pipeline and change the damaged parts of pipeline*	
Check is performed by: *Р. Иванов*	Signature: ….

Correctly performed and filled data checks show up-to-date information about local ventilation systems' status and can serve as a basis for corrections, repairments and improvements in them. In case operational personnel can't reach satisfactory results even after measures applied, the problems should be raised to an upper management level – chief engineer, ventilation manager, in order to clear the reasons for bad performance of the system and for adequate measures to be undertaken.

Local ventilation systems' control measurements

Control ventilation measurements, as stated above, should be performed after any change of ventilation installation - lengthen of pipeline, regulators relocation, replacement of pipeline sectors etc. Some changes might arose from regular checks and controls. Ventilation measurements as a first should proof that design parameters are met and if practice require corrections in in the project or its realization (Kertikov, 1995).

Featuring parameters of on local ventilation system are clearly presented and explained in McPherson, 1993 and in Stefanov,1991. One example of forced scheme with one fan are as follows:

- air flow through the fan (Qv),m^3/s;
- air flow, supplied to the face (Qo),m^3/s
- fan static pressure (Ps),Pa
- fan total pressure (Pt),Pa
- system supply coefficient (p=Qo/Qv).

Assessment of the above stated parameters need special knowledge about aerodynamics of flows in local ventilation systems, should be fulfilled by experienced personnel in accordance with requirements for ventilation measurements, as explained in Stefanov,1991. More detailed explanation about consequence in measurements, main links between values, devices used in practice is given in Kertikov, 1995. One very important point is availability of measuring devices, which in minimum should be the following:

- anemometer to measure air flow velocity in a pipeline and in an accompanying flow in mine working;
- manometer to measure total and static pressure in a pipeline and of a fan;
- combine Pito tube to take sample for pressure of a flow in a pipeline and to transfer the information to the manometer. It can be used also for direct evaluation of velocity in a flow;
- psychrometer for air humidity and further density evaluation;
- barometer for barometric pressure measurement;
- combined gas detectors for measuring concentration of gas impurities at a face and along the air flows;
- gas leak detectors for control of air leaks and recirculation in low velocities sectors.

These list of measuring devices is absolutely necessary for required by Pravilnik 1992, Pravilnik 1971 gas, flow and pressure surveys. Measurement devices need calibration and regular examinations in a certified laboratory at least once a year unless stated differently in technical papers of producers. In case units are used more often they underpass calibration every 6-8 months.

Control measurements results should be classified and well presented for further analysis and correct measures when some of parameters are out of order. It is very useful for one enterprise to prepare typical forms for registration of controls for all types of local ventilation systems – forced, exhaust and with overlap. Such forms should include the following data:

- place and time of measurement;
- data for object – dead end part, face, adjacent; gallery;
- data for ventilation system and for fan general description;
- classified information of measurements and post-measurement calculations, where necessary;
- overall system's performance – coefficients, effectiveness, parameters.

One example of control measurements and assessment of forced local ventilation system is given in tables 2 and 3.

Table 2.
Form 1 – general data

Date and time:	*15:40*
Place:	*6 gallery*
Geometrical data:	
Cross section,m^2	*12*
Length,m	*120*
Design length	*260*
Required air flow, m^3/s	*6,5*
Cross section of adjacent working,m^2	*14*
Data for ventilation system:	
Fan type:	*BM-8M*
Fan number:	*3BM*
Motor power, kW:	*55*
Angle of the blades	*+20*
Work wheel diameter, mm	*800*
Pipeline diameter, m	*800*
Length of pipeline, m	*105*
Length of pipeline sectors, m	*10*
Type of connection between sectors	*zip*
Number of connections, number	*10*
Length of pipeline in the adjacent gallery, m:	*10*
Number and type of local resistances: 1. One bend at 90 degree 2. ___________________________	*1*

These forms (table 2 and 3) are models. They might be transformed according to special features of the company and its local systems. The models, presented here, consist only minimal amount of data and any additional information might bring more confidence in presentation of results.

Table 3.
Form 2 - measurements

Ventilation measurements	
Barometric pressure, hPa	*910*
Air temperature at face, ^{O}C	*24*
Air flow of fan - Qv ,m^3/s	*7,8*
Fan total pressure of P_t,Pa	*2900*
Air velocity in a pipeline, m/s	*15.5*
Air flow at face – Q_0,m^3/s	*6,9*
Air velocity in dead-end working – Uc,m/s	*0.58*
Air flow in dead-end working – Qc,m^3/s	*7*
Air velocity in adjacent gallery – Ua,m/s	*0.9*
Air flow in adjacent gallery – Qa,m^3/s	*12.6*
Air temperature in adjacent gallery – Ta,m^3/s	*21*
System's parameters	
Face supply coefficient $p=Q_0/Qv$	*0.88*
Dead-end working supply coefficient – z= Qa/Qv z>1.43	*1,6*
Fan's efficiency	*0,45*
Electrical power,kW	*45*
Comment:____	
Measured by: Ivanov	Signature: +++++

All presented measured results follow methodology given in . McPherson (1993), Stefanov T.,1991 and Kertikov V., Iv. Velchev (1995). The most often mistakes and difficulties exist in measurements of fan air flow (Qv) and air velocity in a pipeline. These are due to close location of measuring points to the fan motor and non-regular profile of velocity there. Other difficulties arose by hardly to reach locations (narrow, high places) where accuracy might be not satisfactory enough. Well designed and built ventilation system should have appropriate holes for portable devices or permanent units for measurement. One example is the diffusor shown on fig. 3. It is mounted on fan's inlet, has safety grid and ring to measure static pressure. Then very easily air flow, inflowing into the system, can be calculated.

Along pipeline length nozzles, orifices and other air-dynamical units might be built in to assist in pressure and flow measurements and controls.

Conclusion

Ideology of local ventilation system's control and required measurements to achieve cost effective and at the same time – ensuring safety work environment, presented in this paper might serve in several directions.

As a first for mine companies it is very important to keep ventilation systems – local and main ones, in correct interaction between them. This means to maintain energy power cost for both systems at such regulation so as to supply required air flows in sufficient amount to the local systems.

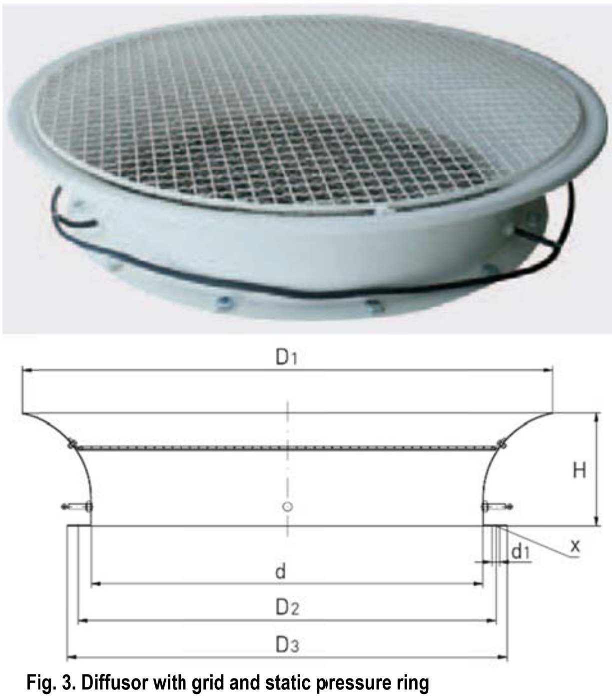

Fig. 3. Diffusor with grid and static pressure ring

As a second – for other underground objects, where dead-end configurations are part of their construction. Requirements, stated in safety regulations for underground coal and metal mines should be taken into account to other underground objects, although it is not explicitly written for them. Reaching great safety standards for all underground objects is task, which solution should be searched and found. Author's expertise in design and control of mine local ventilation systems can serve as an initial step in that direction.

Results classification in a specially created forms and further systematical analysis of obtained data might be very useful in forecast of future potential problems in the process of this particular local system and even more – in other systems, operating in similar conditions.

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