Original paper

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Determination of air flow in mine workings with new generation anemometers *

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Issues on the method of measuring the air flow rate in a mine are considered. The analysis of the methods used to measure the air flow rate is carried out, a new method of measuring "in the center of the cross section" of mine workings, which provides a smaller measurement error, is substantiated and proposed. The choice of the method of measuring the air flow rate is important for providing effective and high quality underground ventilation. The new generation APR-2m anemometer is presented, its description, technical characteristics and functional capabilities are given. Certification of the anemometer was performed by the Sertium Intersectorial Certification body (MOS Sertium), repeatedly conducted tests confirmed high quality and reliability of the device. In addition, the standards for calculating anemometers for mines and ore mines were approved by the State Technical Surveillance Committee of Russia in 1996 and are currently being applied. Measures are proposed aimed at improving the reliability of mine ventilation and creating safe working conditions in mines.

Keywords: *mine, mine working, anemometer, standards for calculating anemometers, air flow rate, measuring method, labor safety.*

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INTRODUCTION

Providing mines and ore mines with the necessary amount of air has always been and is a mandatory condition for creating safe working conditions. Unfortunately, in determining the air flow rate we currently use the measurement methods developed in the remote past, when the main means of cargo transport were sledges and horses, and the cross-sectional area of mine workings did not exceed 5-6 sq.m. Over the years, a lot has changed in mines and ore mines, powerful electric locomotives and conveyors were introduced, and the cross-sectional areas of mine workings now reach 15-20 sq. m with the headroom of 4-5 m. Instead of old anemometers ASO-3 (ACO-3) and MS-13 (MC-13), new types of devices have long appeared, more than 90% of mines and ore mines are now equipped with anemometers APR-2m (АПР-2м) of the new technical level, but though having at hand new generation devices we are still forced to use the measurement methods proposed back in the 18th century - "in section", "in front of yourself" and "one-point method".

NEW GENERATION ANEMOMETERS

ASO-3 and MS-13 anemometers had air flow rate measurement ranges of 0.3 to 5 m/s and 1.0 to 20 m/s, respectively.

APR-2m anemometer (Fig.1) provides measurements of air flow rate in the range 0.1 to 50 m/s with absolute error which is several times less. Besides air flow rate measurements, APR-2m anemometer provides simultaneous measurement of air flow temperature and pressure and can operate in manual, automatic and remote measurement modes. Moreover it is compatible with a computer, keeps performed measurement results in its working memory and can print them out. Technical characteristics and functional capabilities of APR-2m anemometer are presented in the following *Table*.

Due to their high quality, APR-2m anemometers are also used by the enterprises belonging to other industries, including Rosatom State Corporation, which uses them to control the air cooling of nuclear reactors. These devices provide for the transmission of measurement results up to 1000 m from the installation site, which is essential for such enterprises. The same advantages of APR-2m anemometers, that have self-contained power supply, can be used during mine ventilation control in emergency situations, when power supply to the mine is cut off. Coal companies and mine rescue brigades (VGSCh) would benefit from having 1-2 sets each for such purposes.

MEASUREMENT METHODS OF AIR FLOW RATE

Along with the availability of new types of instruments, it is also necessary to find new ways of air flow rate measurement, one of which is one-point method. One of the founders of mining aerology in Russia prof. ***M.M. Protodyakonov*** wrote

* *As a matter for discussion. – Ed*

about the permissibility of one-point measurements many years ago: «… *having once studied in detail the location of air flow rates along the section, later you can measure it only at one point, because all the other rates change accordingly. It is obvious that the most convenient way is to select a point that corresponds to the average air flow rate in this section and continuously perform measures in it.» [1].*

Unfortunately, nothing has changed in the 100 years since the first publication, and air flow measurements in mines and ore mines are still being performed according to the methods developed for 18th century instruments, which are unsuitable for the new types of anemometers.

Author of the present article, who worked as the head of the ventilation unit at one of the mines of Donbass, and now is engaged in production of APR-2m anemometers, having extensive experience in performing air flow measurements in mines and having published several articles on measurement methods and application of anemometers of the new generation (his first publication was in 1971 in Ugol' Ukrainy journal), proposes not to search for a point with an average air flow rate in the section, which takes quite a long time, but use as a basis for the measurements the rate "in the center of the cross section" of mine working [2, 3, 4].

Figure 1. Mining anemometer APR-2m

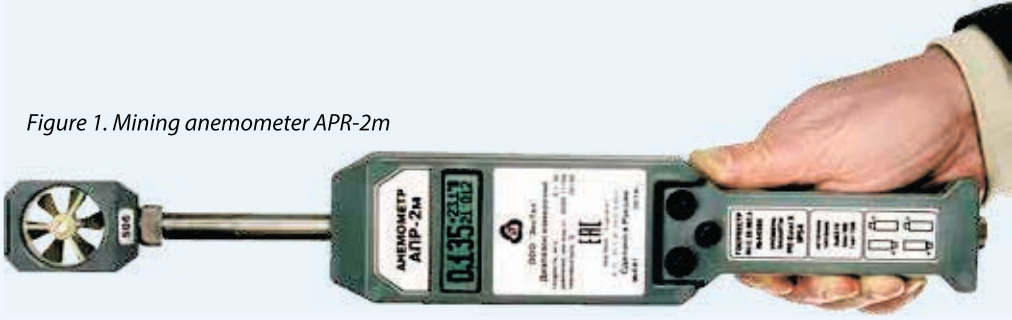

Table 1. Technical characteristics and functional capabilities of APR-2m anemometer

Features	Values
Measurement range:	
–rate, m/s	0,1 – 50,0
–pressure, mm w. g.	8 500-11 700
–temperature, °C	-20 + 60
Measurement error, where V is a rate, m/s	+/-(0,05+0,05V)
Number of measurements in sequence	600
Possible duration of measurement, days	6
Number of parameters induced: total/including those performed simultaneously	20/6
Printing out measurement results using a computer, total	36
Display active window, sm^2	9,0
Installation of computer programs, pcs.	2
Device operation in the following modes: automatic/remote	Yes
Measurement of the following parameters: pressure/temperature	Yes
Transmission of measurement results online up to 1000 m	Yes
Data transmission interface	Yes
Recording number, date and time of measurement	Yes
Presence of charging indication: power supply elements/voltage values	Yes
Automatic disconnection of supply when the device is not being used	Yes
Duration of continuous operation without replacement of power supply elements, h	1 200
Computer compatibility	Yes
Certificate of inclusion in the State Register of MI and TR CU certificate	Yes
Anemometer manufacturer	«Eko Tech» LLC (Moscow)

With the introduction of automated air flow control systems, mines and ore mines have switched to the rate measurements performed with the sensors fixed at one point. The average air flow rate in this case is being determined by the application of the multiplying coefficient (Kpv) stipulated by the Regulation on aerogas control approved by the Federal Service for Environmental, Technological and Nuclear Supervision of Russia (Rostekhnadzor). Taking the method of air flow rate measurement by the sensors fixed at one point as a basis for automated systems, it is necessary to solve the issue of one-point measurement by portable anemometers of the next generation as well. There are certain reasons to do so, let's take a closer look at them.

For example, when using the "in section" method (the most common one) a portable anemometer can perform a measurement at a maximum height of 2.5 m, which means that in case of a higher headroom the measurement is actually performed in the center of the cross section, in the air flow of the maximum speed. Taking the rate value as the average one during this kind of measurement, we get a very significant error (10-15%) towards the air flow increase while it is actually absent.

The second factor to be taken into account is that numerous measurements made in airless ends have shown that when the device passes the section, the anemometers's vane rotates according to the speed of its movement, so by moving the device along the section, we introduce an additional error, which gives a very significant measurement error of the flow rate towards its increase.

In addition to the traditional methods of measuring the air flow rate by portable anemometers - "in section", "in front of yourself" and "one-point method" - it is also necessary to include in the Safety Regulations the method of measuring "in the center of the cross section" of mine working. It should be noted that the center of the cross section should be understood as the "core" of the airflow having the maximum speed, which generally occupies at least 30-40% of its section, so the error in determining the center of the cross section of mine working (the core of the flow) is almost impossible to make.

The measurement of the average velocity "in the centre of the cross section" should be carried out with a decreasing coefficient (Kpn), which is as a rule equal to 0.85. It may vary slightly depending on the section of mine working and on the air flow, but this will not significantly affect the accuracy of the determination of the average rate.

Any method of air flow rate measuring has its error, so while measuring it is necessary to use a method having a lower error, which is the method of measuring "in the center of the cross section" of mine working. One-point measurements are currently used for stationary air flow control systems. It is also necessary to recognize such a method of measurement when

carrying out measurements with portable anemometers, which is now actually performed at mines and ore mines, but is not legalized by the Federal Service for Environmental, Technological and Nuclear Supervision of Russia (Rostekhnadzor) officially.

The clause 193 of the current Coal Mine Safety Regulations states that "the procedure of air flow measuring in mine working shall be determined by the technical manager (chief engineer) of the mine". It is not quite clear how we should understand this requirement. It seems that the developers of the Safety Regulations sheded all the responsibility for making a decision on the method of measurement and shifted it onto the chief engineer of the mine, which is not quite fair.

The Operating Manuals for Thermoanemometers and Acoustic Instruments do not specify proposed methods for airflow rate measuring. The moving of the temperature sensor along the section causes its cooling, which may give a false idea of the presence of additional amount of air while it is actually absent. The results are also being distorted when acoustic and tachometric anemometers of APR-2m type are moved along the section.

STANDARDS FOR CALCULATING ANEMOMETERS

Standards for calculating anemometers for mines and ore mines were approved by the Federal Mining and Industrial Inspectorate of the Russian Federation (Gosgortekhnadzor) relatively recently (letter No. 04-35/314 of 01.11.1996), before that there were only recommendations determining the provision of mines and ore mines with anemometers based on the number of mine overseers in two shifts, who carried out control of mine ventilation. With such "recommendations" any number could actually be counted. The author published an article proposing his own methodology for calculating anemometers in "Labor Safety in Industry" journal in 1996, after which he was invited by the Committee management to an extended panel board to present a report on the methodology developed by him. As a result of the meeting Resolution 30/1/P-434 of July 23, 1996 was adopted, and on the basis of the clause 3.2 of the said Resolution the Federal Mining and Industrial Inspectorate of the Russian Federation (Gosgortekhnadzor) sent a letter to the heads of the districts ordering "to demand from the heads of mines and ore mines the provision of enterprises with anemometers in accordance with the attached calculation standards". At the moment these standards are becoming forgotten, many people do not know about them at all, which adversely affects the control of ventilation of mines and ore mines.

CONCLUSIONS

For all the types of portable anemometers, the most accurate method of measurement is the one "in the center of the cross section" of the airflow. The Federal Service for Environmental, Technological and Nuclear Supervision of the Russian Federation (Rostechnadzor) should recognize and legitimize the method of air flow measuring "in the center of the cross section" of mine working by portable anemometers. It is also necessary to include the standards for calculating anemometers for mines and ore mines in the Safety Regulations' requirements.

Inclusion of the method of air flow measurement "in the center of the cross section" and the standards for calculating anemometers in the Safety Regulations for Mines and Ore Mines will contribute to obtaining objective results during ventilation control and creation of safer working conditions at production sites.

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Title
DETERMINATION OF AIR FLOW IN MINE WORKINGS WITH NEW GENERATION ANEMOMETERS

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Abstract
Questions about the method of measuring the speed of air flow in a mine are considered. The analysis of the methods used to measure the air flow velocity is carried out, a new method of measuring "in the center of the cross section" of the mine workings is substantiated and proposed, which provides a smaller measurement error. The choice of a method for measuring the air flow rate is important to ensure efficient and high-quality underground ventilation. The new generation APR-2m anemometer is presented, its description, technical characteristics and functionality are given. Certification of the anemometer was carried out by the MOS "Certificate", repeatedly conducted tests confirmed the high quality and reliability of the device. In addition, the standards for calculating anemometers for mines and mines were approved by the Gosgortekhnadzor Committee of Russia in 1996 and are currently being applied. Measures are proposed aimed at increasing the reliability of ventilation of mines and creating safe working conditions in them.

Keywords
Mine, Mine working, Anemometer, Standards for calculating anemometers, Air flow rate, Measurement method, Labor safety.

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On air flows speed measurements by anemometers of new generation

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The article analyzes the methods used to measure speed, substantiates the method of measuring "in the center of the cross-section" of the development, proposes measures aimed at creating safe working conditions in mines.

Key words: *mine, excavation, anemometer, air flow rate, measurement method, labor safety.*

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REVIEW for the article A. Meshcheryakov "On air flows speed measurements by anemometers of new generation"

The article is devoted to a very topical issue for coal mines, namely, the issue of ensuring safe working conditions in them. Undoubtedly, one of the ways to ensure such conditions is the high-quality ventilation of the mine workings, and here the method of measuring the speed of air flows is very important, providing minimal errors when making measurements.

A. A. Meshcheryakov analyzed the recommended measurement methods and proposed a new method - "in the center of the section", which provides a smaller measurement error.

The author of the article has extensive experience in resolving issues of airing mines, he worked in the mines of Donbass for more than 20 years, of which 15 years - as the head of the VSU section and the chief engineer of the mine. While serving as the head of the VSU site, he defended his thesis on the development of ways to improve the efficiency of mine ventilation. It is noteworthy that in the list of references to the article his publication is indicated in the journal "Coal of Ukraine" for 1971. The article is called "On the issue of determining air flow by measuring speed at one point", that is, the author has been dealing with this problem for more than 40 years, and his conclusions about the necessity of the method of measuring "in the center of the section" can be trusted.

For almost 20 years, the author has been dealing with another important problem for the coal industry - with his active participation, the APR-2 anemometer with which coal mines are equipped was developed and mastered in serial production. For the development of serial production of APR-2, A. A. Meshcheryakov was awarded the prize named after academician A. A. Skochinsky. A few years ago he received a patent for a mine anemometer APR-2m, which currently has no analogues in its technical capabilities.

Taking into account the above, I consider the publication of an article by A. A. Meshcheryakov in the "Ugol" journal very useful and timely, the article is aimed at solving a very important problem - improving work safety.

NOSENKO Vyacheslav Demyanovich *Mining engineer, Ph.D. of tech. sciences, academician of International Academy of Ecology, Man and Nature Protection Sciences*

Monitoring the speed of air flow in the mine workings is an indispensable condition for creating safe and comfortable working conditions in them. In this case, the choice of the method of measuring speed is very important, since the accuracy of measurements, and, consequently, the state of the dust and gas regime of the mines, largely depends on it.

For many decades, traditional measurement methods have been recommended: "in cross section", "in front position" and "point by point". The first is most common - "in section" and less applicable - "by points", since it is the most labor-intensive, requiring at least 40-60 minutes to conduct just one measurement. The same method is also less accurate, since significant fluctuations in the air supply can occur during the measurement, introducing a significant error in determining the average speed. When measuring air flow in a mine, this method, as well as the method of measuring "in front position", are used extremely rarely.

More than 80 years ago, one of the founders of mine aerology in Russia, prof. M. M. Protodyakonov: "... having once studied in detail the location of the velocities over the cross section, in the future we can be content with measuring only at one point, because all other velocities vary in proportion to this. Obviously, it is most convenient to choose a point corresponding to the average speed of a given section, and to constantly measure in it "/ 1 /.

It is very difficult to determine the point corresponding to the average speed each time you measure, since for this you need to carry out a complex of measurements, which takes a long time. The author of the article, having carried out a large volume of measurements, came to the conclusion that it is permissible to take measurements of the average speed in the center of the working section / 2 /. At the same time, the place of measurement can be taken not as a geometric point in the center of the cross section of the mine, but as the core of the air flow moving at maximum speed, which greatly simplifies measurements.

In workings with a cross-sectional area of up to 8 square meters maximum speed is observed on an area of 30-40% in the center of the cross section of the mine. As the cross-sectional area that currently has a place in most mines increases, the area of the flow core increases at maximum speed, which facilitates the production of measurements and increases their accuracy.

The determination for all sections of one measurement site eliminates the need to determine the average velocity measurement point in each individual case. When determining the average speed *Vcp* across speed *Vц* in the center of the working section *Vcp* = 0,85 *Vц*, m/s.

The error of measurements made by the method "in the center of the cross-section" is significantly lower than the error of measurements "in the cross-section", since the error caused by the uneven contour of the device over the cross-section is excluded. When making measurements using the "in cross-section" method, in workings with a height of 3 m or more, it is impossible to ensure a uniform contour of the device over the entire cross-section, since the device in an outstretched arm can be raised to a height of about 2.5 m, and in many cases workings 3 m and more.

In such workings, it turns out that the measurement is supposedly carried out using the "in cross-section" method, but in fact it is a method of measurement "in the center of the section", and we do not use a reduction coefficient, which leads to an overestimation of speed readings.

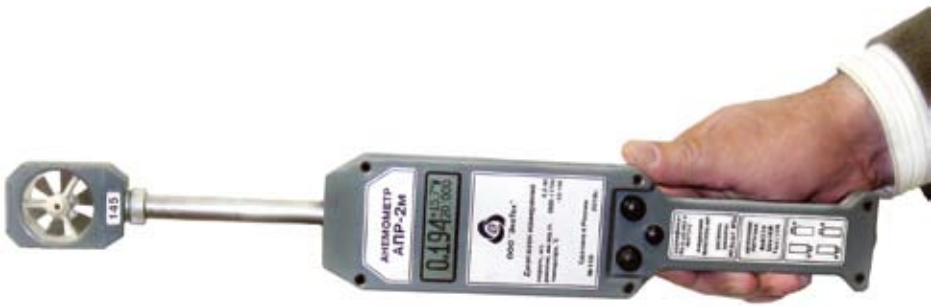
Measurements made by the APR-2m anemometer in an unventilated room by uniformly circling its cross-section showed that the speed with such measurements is 0.2-0.3 m / s, since the impeller of the device is very sensitive to moving it in space, that is why the speed indicated is actually proportional to the speed of movement of the device over the cross section. And this situation is typical not only for APR-2m, but also for other types of highly sensitive devices. For example, when using hot-wire anemometers, which are based on the principle of cooling a heated string, it is also unacceptable to measure the average speed using the "cross-section" method, since the string cooling in this case occurs not only from the air flow velocity, but also from the speed of movement instrument when measuring. The same problems arise when using acoustic devices, here also an additional error arises due to the movement of the device along the production cross section.

Given the introduction of a new generation of anemometers, such as APR-2m and others, it should be recognized as the most reliable way to measure at one point - "in the center of the section." The method of measuring at one point is currently used when installing stationary sensors; there is no other way for them. However, inertia of thinking, as well as the lack of an organization that has taken responsibility for deciding whether to use this measurement method for new generation anemometers, prevents us from using portable anemometers for measuring in the center of the section.

In the "Operation manual" of the SRSV 01 air flow rate sensor developed by InGorTech, in paragraph 2.6, the methodology for calculating air flow when installing stationary sensors / 3 / is given. The methodology described in the Manual fully coincides with the methodology for portable anemometers proposed by the author of the article.

The only difference is that when installing stationary sensors in the zone of reduced speeds, at a distance of 20 cm from the support of the mine, an increasing coefficient is used to determine the average speed, and when measuring using APR-2m portable anemometers in the "center of section" method, a decreasing coefficient should be used .

In our opinion, the Manual should recommend the use of an APR-2m anemometer with the same initial measurement threshold of 0.1 m/s as a control device. It would be methodologically correct to indicate in the Manual that the air flow in the mine is determined by the method of measuring the APR-2m anemometer "in the center of the section" of the mine (*Vц*) , and not "in cross-section", as it is now said, after which the same anemometer measures the speed at the installation site of the stationary speed sensor (*Vд*) , then the coefficient N is determined, taking into account the position of the stationary speed sensor , equal to $N = 0{,}85\,Vц/Vд$.



Mining anemometer APR-2m

The APR-2m anemometer, unlike other types of instruments that provide only the measurement of air flow in manual mode, also allows measurement of speed, pressure and temperature in automatic and remote modes, while it provides speed measurement in the range from 0.1 to 50 m/s. The measurements made by the APR-2m anemometer are stored in the memory of the device and can later be printed on a computer. With the cost of automatic air control systems of tens of millions of rubles, the presence of portable anemometers in the mines, which can be used to automatically monitor ventilation networks, is a very promising area both in order to save material resources and ensure safer working conditions .

Safety rules in coal mines should provide a method of measuring "in the center of the section", as well as the standards for calculating anemometers for mines, approved by the Gosgortekhnadzor (04-35 / 314 of 11/11/1996), which will increase the safety of work in mines.

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