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Study on the Application of the Basic Parameter Automatic Monitoring Device for Gas Extraction Drilling

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Abstract Mine gas is a gas mainly composed of coalbed methane, which seriously threatens the life safety of the miners and the normal production of coal mine. Meanwhile, as an efficient clean energy, the enhanced gas extraction is an important method to improve the utilization of resources. In order to effectively detect the parameters of gas extraction borehole, optimize the extraction process and solve the work efficiency of gas extraction monitoring, a basic parameter automatic monitoring device for gas extraction drilling is developed, which has obtained the national utility model patent. This device can be used in real-time, continuous and automatic monitoring of the negative pressure, gas concentration, flow and other basic parameters of underground drill pump. As a result, not only can it timely evaluate the effect of extraction drilling, but make the correct adjustment to improve the drilling rate and utilization rate.

Keywords Gas extraction, Gas treatment, Automatic monitoring, Extraction drilling

Introduction

Gas is composed of a variety of combustible gases, and coal mine gas refers to the natural gas used by people. Coal mining method in a variety of forms, but as a result of various coal production enterprise for mechanical equipment investment, and implementation of safe production regulations have certain differences, which may result in gas suffocation, burning, even explosion problems[3]. As a kind of catastrophic material, gas has the characteristics of explosive, suffocation and outburst, which seriously threaten the life safety of the miners and the normal production of coal mine. As a kind of high quality, clean, efficient energy, it has important development and utilization value. As a greenhouse gas, untreated or directly discharged into the atmosphere can cause serious environmental pollution and waste of resources.

Therefore, enhancing gas extraction is an important way to reduce gas disasters, reduce environmental pollution and improve resource utilization. As a result, gas extraction has the advantages of ensuring the safe production of coal mines, protecting the atmospheric environment, developing and utilizing high-quality clean energy.

Gas extraction is mainly composed of a set of negative pressure pumping units which consist of the arrangement of boreholes, connection pumping pipes and installation of pumping pumps. Each component determines the extraction effect of the device. For the extraction drilling, the parameters such as negative pressure, gas concentration and flow rate are the most direct indexes to measure the effect of drilling and extraction. At

present, due to the constraints of geological conditions and technical methods, the drilling holes are mainly laid in the underground working face, which will cost more manpower, material resources and financial resources to the on-site measurement of drilling and extraction parameters in the actual production process, which greatly reduces the working efficiency. In view of this, it is urgent for a set of equipment to monitor the negative pressure, gas concentration and flow rate of the borehole in the ground in real time, continuously and automatically, so as to timely evaluate the effect of drilling extraction, and make the correct adjustment to improve the extraction rate and utilization ratio of boreholes.

According to the above situation, the purpose of this study was based on the main forms and following the migration law of the gas flow in coal seam as the principle, design and provide a kind of ability of drilling extraction of negative pressure under the mine, gas concentration, flow parameters such as real-time monitoring device, and when appears the condition of leakage, the device can quickly take measures to effectively improve the gas extraction rate and utilization rate.The device takes PLCCPU221(29)as the main controller, and through the gas concentration detector, gas pressure detector and flow detector, the basic parameters of the extraction and drilling are measured. The data acquisition device makes a simple processing of the analog quantity and then enters the main controller. The upper computer USES the configuration software to carry out real-time data exchange through the Profibus(46) communication mode and the PLCCPU221(29), and the basic parameters of the drill hole can be observed every five seconds through the display screen of the upper computer, which saves a lot of human and material resources. It is helpful to improve the extraction rate of borehole and gas utilization rate.

Purpose and development of gas extraction technology in coal mines

For coal mines in China, gas accidents are generally divided into coal and gas outburst, gas explosion and gas asphyxiation and combustion. Gas combustion, explosion and asphyxiation are mainly caused by gas accumulation to a certain volume fraction, for example, when the volume fraction of gas is 5% ~ 15%, gas combustion accident can occur; If gas accumulation causes oxygen to be reduced to 12%, it can cause shortness of breath and even death. The massive emission of gas from coal mines not only wastes energy resources but also seriously pollutes the environment. Meanwhile, methane is the main component of gas, which is a strong greenhouse gas. Therefore, gas extraction mainly has the following objectives: 1) prevent gas emission, reduce the gas emission and reduce the accumulation of gas, and provide favorable conditions for the ventilation of coal mine: 2) improve the coal strength of coal mine, reduce the energy of gas storage in coal seam of coal mine, and prevent gas outburst: 3) develop and utilize clean and efficient energy: 4) to reduce the pollution of the coal mines[1]. According to the safety regulations of the coal mine, in accordance with the safety regulations of the coal mine, it is necessary to establish a permanent gas drainage system on the ground of the coal mine or temporary gas extraction from underground gas.

After decades of development, China's coal industry technology has made great progress, and gas extraction technology has developed greatly. Generally speaking, the development of coal gas extraction means in China can be divided into four stages: coal seam gas high permeability extraction technology. In the early 50 s of the 20th century, drilling L drainage technology was first applied in Fushun area, thickness and high permeability of coal seam extraction from job, and got some achievements, the gas safety of deep mining area to the stage of development is an effective guarantee; Adjacent layer unloading pressure technology. In the mid-1950s, the Yangquan mining area experimentally used the perforated drilling technique, and succeeded in extracting the gas from the adjacent strata, and obtained the support and use of multiple mining areas. Low permeability enhanced extraction technology. Around in the 60 s of the 20th century, our country began to grid experimental dense holes technology, coal seam water injection technology and improved extraction techniques such as loose blasting technology, due to various reasons, is still not widely used; Comprehensive extraction technology. , appeared in the 1980 s,, with the vigorous promotion and use of sublevel caving and fully mechanized methods, make measures of mining roadway layout optimization, but also result in coal face gas emission growth continuously, so in order to reduce the gas emission, China began to promote the use of integrated extraction technique [2].

Several main flow forms of gas in coal seam

Classification and characteristics of gas flow field

Table 1: Classification and characteristics of gas flow fiel

Classification	Definition	Characteristics
The steady flow field	In the steady flow field, the gas flow velocity, flow direction and pressure of any point do not change with time. Therefore, the gas flow is called stable flow.	1. Has the fixed gas source; 2. The gas pressure of the outlet and inlet shall not change with time; 3. The coal seam is only the passage through which the gas flows, so the gas pressure at each point of the flow field remains unchanged.
Unsteady flow field.	In the unsteady flow field, the gas flow velocity, flow direction and pressure of any point in the flow field change with time, and the gas flow in the field is unsteady flow.	1. There is no fixed gas source, and the coal seam is both the source of gas and the channel of gas flow; 2. With the continuous outflow of gas, the gas pressure in the coal seam decreases and the flow field expands continuously. 3. The gas pressure and pressure gradient of each point are also changing.

Basic forms of gas flow

The gas in the coal seam mainly has three basic flow forms one-way, radial, and spherical. In the actual coal mine, due to the different natural conditions, such as the heterogeneity of the coal seam and the variability of the lithology of the top floor of coal seam, in the actual the gas's flowing in laneway and borehole is complex, and sometimes it may be a combination of various basic flows. For the coal rock stress response field, the initial condition is the initial stress and the strain field of the coal rock [3].

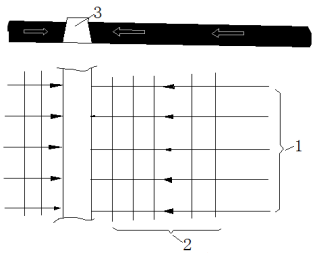
$$\Omega\begin{cases}\sigma_{ij}=\tilde{\sigma}_{ij} & \text{The initial stress}\\ \varepsilon_{ij}=\tilde{\varepsilon}_{ij} & \text{The initial strain}\end{cases},t=0$$

Table 2: The type of gas flow in the actual well and borehole

Engineering classification	The position in the coal seam.	The flow field type	Note
Roadway	Laneway height ≥ seam thickness	One-way flow	\
	Laneway height < seam thickness	One-way flow	Start with radial flow, after discharging for a period of time, convert to one-way flow
Drilling	Piercing drilling (including ground drilling)	Radial flow	\
	Bedding boring	One-way flow	Start with radial flow, after discharging for a period of time, convert to one-way flow
Wellbore,stone door	\	Radial flow	The coal seam is thicker and has just opened the coal seam, which is similar to the ball to flow and then the radial flow

The one-way flow of gas in the coal seam

The coal seam gas flows in a single direction, and the streamline is parallel to each other, as shown in Fig 1.



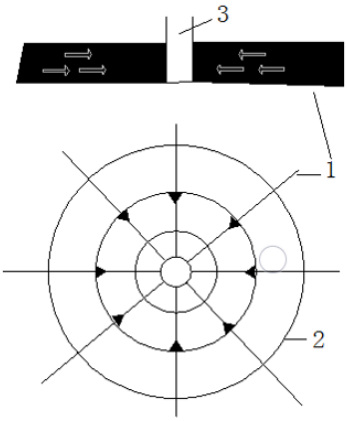
1. The flow; 2. Isobaric line; 3. The roadway

Figure 1: Schematic diagram of one-way flow

In the actual coal seam, the one-way flow of gas is mainly transported through the fissure system and flows in the fissure. In the actual coal seam, the fracture The gas pressure line is a group of concentric circles, the gas flow line develops along the radial direction of the circle, as shown in Fig 2. development is not consistent, and

it is affected by the excavation stress, which causes the crack opening degree to change, causing the permeability heterogeneity, that is, the flow of gas in time and space is changing [8].

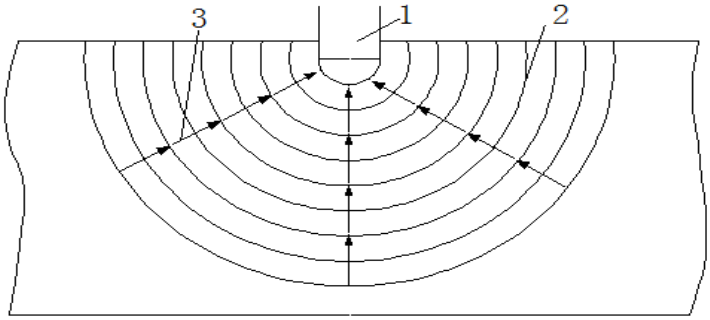
The radial flow of gas in the coal seam



1. The flow; 2. Isobaric line; 3. The drilling
Figure 2: Radial flow diagram [7]

The radial flow of gas in the coal seam

The gas pressure line is a concentric ball, and the gas flow line develops along the radial direction of the ball, as shown in Fig. 3.



1. Uncover the driving face of coal seam; 2.Isobars; 3.Streamline
Fig. 3 Ball flow diagram [7].

The migration law of gas in coal seam

In the laboratory, Wang Youan and Yang Qiluan, the Fushun branch, found that when the particle size of coal was less than a certain particle size, the velocity of the coal particle was basically similar, so the particle size was called the ultimate particle size [10].

The gas flow in coal particles smaller than the limit particle size is the law of diffusion, which conforms to Fick's law of diffusion. When the size of coal particle is larger than the limit particle size, the flow of gas between the coal particles is seepage motion, which accords with Darcy's law.

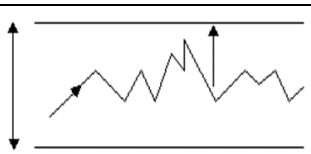
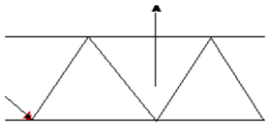
Coal is a typical porous medium, and based on the study of the diffusion mechanism of gas in porous media, it is possible to use a Knudsen number Kn indicating the pore diameter and the relative size of the mean free path of molecular motion:

$$K_n = \frac{d}{\lambda}$$

Where: d - pore average diameter, m.

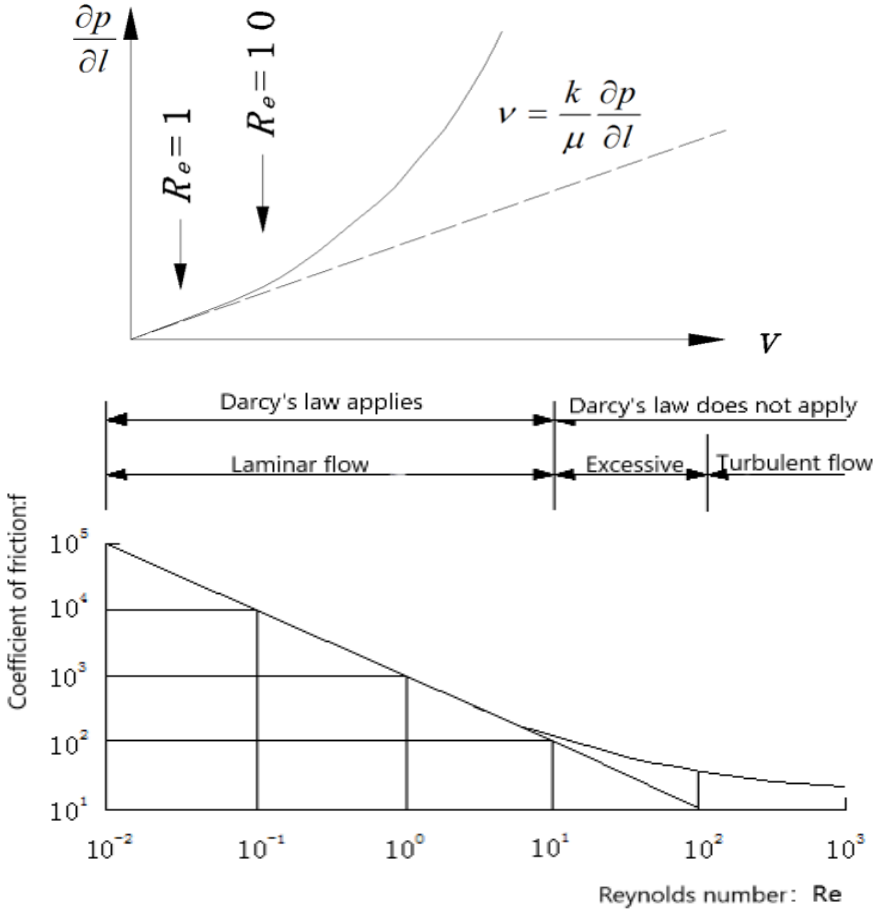
λ- free path of gas molecules, m

Table 3: Diffusion type [7]

Nosen number:Kn	$K_n \geq 10$	$K_n \leq 0.1$	$0.1 < K_n < 10$
classification	Fick diffusion	Norson diffusion	Transitional diffusion
			

In the case of gas containing coal, Kn≥10, because the pore diameter is far greater than the average free path of the gas molecules, so the diffusion is caused by the random movement between the gas molecules, which can be described by the Fick diffusion law.

The low Reynolds number area, Re<1~10, the viscous force is dominant, belongs to the linear laminar flow region, and conforms to Darcy's law; In the middle Reynolds number area, the upper limit of Re is 100, which is the nonlinear laminar flow region and obeys the law of nonlinear osmosis. The high Reynolds number area, Re>100, is turbulent, the inertial force is dominant, and the flow resistance is proportional to the square of the velocity.



According to the theory of gas permeation and diffusion, the gas movement in coal seam is a mixed flow process that contains permeation and diffusion.

In the coal seam, there exist intercommunication fissure networks, along these fissure networks, the free gas flows to the low-pressure working face, and the permeability of the coal body is closely related to the network [12]. At the same time, the gas desorption inside the lump coal is diffused to the fissure. Therefore, the

permeability of gas in the coal seam and the diffusivity of the medium determine the flow condition of gas, and the permeability plays a leading role [3].

Structure and function of automatic monitoring device for gas extraction drilling

Based on the main forms of the gas flow in coal seam and the migration law that the movement follows for principle, the important construction indexes and parameters that need to be tested in the process of gas drainage are determined, such as hole depth, borehole and wind tunnel Angle, borehole elevation Angle, etc [11]. The important parameters in the process of gas drainage, such as the height of the final hole and the top boundary of the coal seam, the projection length of the borehole in the direction of the wind tunnel, and the vertical projection of the final hole point of the borehole to the distance of the wind roadway [4], will also directly affect the drilling and drainage effect, and the key factor is the drilling arrangement parameters of coal seam in different mining areas. This device can be combined with the existing detection technologies, such as gas concentration, gas pressure, flow parameters, In the face of pumping, the basic parameters such as negative pressure, gas concentration and flow are monitored in real time, continuously and automatically. Timely and effective evaluation borehole extraction effect, make the correct adjustment to improve drilling extraction rate and utilization rate.

The automatic monitoring device of gas extraction drilling is divided into well upper part and underground part:

Well upper part: Communication terminal (28), PLCCPU221(29), Alarm indicator light (30), Alarm bell (31), 220V ac power (32), Alarm emergency stop switch (40), Start button (41), Stop button (42), EM277 communication module (43), Profibus cable (46), Upper computer (47). The PLCCPU221(29) acts as the master controller and communicates with the computer through the communication cable.

The underground part : Data acquisition device is composed of EEPROM(1), Embedded controller (2), Rs-485 interface (3), Power regulator (4), Module converter (7), Multiplexer (8), Gas concentration detector (14), Gas pressure detector (15), Flow detector (16), Intermediate relay (17), Solenoid valve coil (18), 24V switch power (19), Rs-485 signal repeater (20). It collects the data mainly through the gas concentration detector, gas pressure detector and flow detector stalled in each pipe, and the data collected will be sent to the data collection device for simple processing. Then it will be sent to PLCCPU221 (29) through the RS485 communication cable. At this time, PLCCPU221 (29) will summarize the data, and finally the upper position will display the measured parameters. This device allows the monitored data to appear on the display screen every 5 seconds. Also, when the pipe fails, the PLCCPU221 (29) controls the solenoid valve and closes the valve. The schematic diagram is shown in Fig4 and Fig 5.

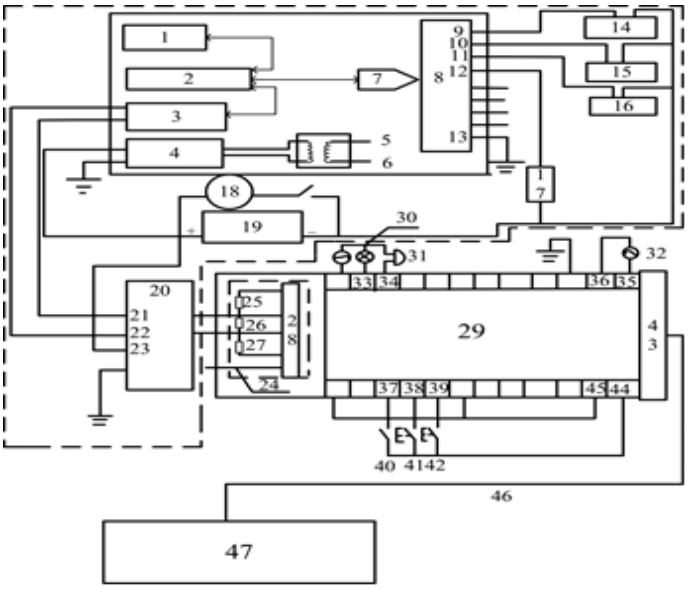


Figure 4: Electrical schematic diagram of basic parameter automatic monitoring device for gas extraction and drilling

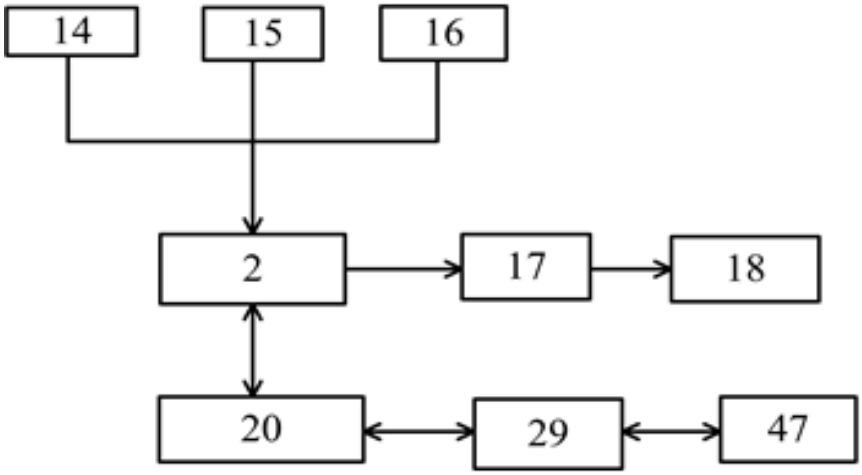


Figure 5: Flow chart of automatic monitoring device for gas extraction drilling

Application process of automatic monitoring device for gas extraction and drilling

Basic parameter automatic monitoring device circuit working process of gas extraction and drilling

In figure 4, the device is divided into two parts. The black dotted line is marked with the part under the mine and the rest is the well upper part. When the device starts working, the 220V ac power (32) is supplied to the PLCCPU221(29), where the zero line of the power supply is connected to N(36), and the fire line is connected to L(35). Press the start button (42) and supply the 24V switch power (19). At this time, the gas concentration detector (14), the gas pressure detector (15) and the flow detector (16) begin to work, and the analog quantity is detected to the three ports of IN1(9), IN2(10) and IN3(11). Through the multiplexer (8) integration, the analog quantity data is transformed into digital data through the analog-to-digital converter (7). At this time, the embedded controller (2) will sort the received data, when the data is too large, the EEPROM (1) will be transferred, the data integrated by the embedded controller (2) will be transmitted out through the rs-485 (3) and the data will be sent out by means of the communication cable. Because the path of the mine roadway will be long, the signal will be enhanced by means of the rs-485 signal repeater (20), the signal repeater Vcc (23) end will be sent with 24V positive electricity. The signal is transmitted by cable to the PLCCPU221(29) communication terminal (28). The cable shield line (24) is connected to the PLCCPU221(29) shell. PLCCPU221(29) received the transmitted data, and its CPU was sent to the Upper computer (47) through the final data sorting through the EM277 communication module (43). The upper computer screen immediately displayed the data collected at different times. The data can be refreshed every 5 seconds.

When the displayed data is abnormal, PLCCPU221(29) will control relay output Q0.0 (33) action, Alarm indicator light (30) begin to work, at the same time, PLCCPU221 issue instructions makes Multiplexer IN4 (12) output voltage signal, Intermediate relay (17) coil electricity and is closed with the normally open contact of the Solenoid valve coil (18) mounted on the pipe. At this time, the Solenoid valve coil (18) is energized, the valve action pipeline is sealed.

Structure process of the basic parameters of automatic monitoring device for gas extraction drilling

In figure 5, before the device starts to work, the PLCCPU221(29) and the Upper computer (47) are completed, and the underground part shall be adjusted to ensure smooth communication. Gas concentration detector (14), Gas pressure detector (15), Flow detector (16) output voltage or current analog quantity, Embedded controller (2) control the whole data collection device for data collection, and the data collected is amplified by the Rs-485 signal repeater (20), and finally sent to the PLCCPU221 in the well. At this time, PLCCPU221 is communicated by data collation and Upper computer (47), and the Upper computer of installing configuration software will display the data of every 5S. If showed abnormal data at a certain moment, PLCCPU221(29) will control data acquisition device let the output voltage signal output, so that the intermediate relay (17) coil electricity, finally solenoid coil (18) electricity, the valve closed [5] .

Results and Discussion

In order to test the practicability and reliability of the automatic monitoring device for gas extraction drilling, it was tested in coal mine. The experimental site was selected at the south well +290m k10 coal seam of Zhongliang mountain coal mine. The basic parameter automatic monitoring device was used to measure the gas concentration, gas pressure and gas flow in the ground. First of all, three drilling holes were named No.1, No.2 and No.3. No.1 borehole was installed the gas pressure monitor (15), No.2was installed the gas concentration monitor (14), No.3 was installed the flow monitor (16), and debugging all parts of well. In addition, the gas concentration, gas pressure and gas flow monitoring were conducted for the holes No. 1, No. 2 and No. 3 by using the manual monitoring method. The two monitoring methods recorded the detected data synchronously every 60 seconds:

Table 4: Parts of data detected by automatic monitoring device for the basic parameters of gas extraction drilling

Parameter / Time/s	Flow/m^2•min^{-1}	Negative pressure /kpa	Concentration/%
0	12.59	13.46	18.1%
60	13.21	14.70	19.02%
120	12.41	13.05	16.4%
180	13.56	15.0	22.04%

Table 5: Parts of artificial detected data

Parameter / Time/s	Flow/m^2•min^{-1}	Negative pressure/kpa	Concentration/%
0	12.51	13.49	18.5%
60	13.25	14.75	19.3%
120	12.48	13.1	17.0%
180	14.0	14.91	22.3%

After a series of measurements and comparing table 4 and table 5, it can be seen that the difference between the data measured by the automatic monitoring device of gas extraction drilling and the data of the manual measurement is within the error range, As a result, we know that the device has the advantages of high accuracy, simple structure, low cost, timely feedback and intelligent adjustment.

Conclusions

The key factors that influence the effect of gas drilling are the layout parameters of borehole under different coal seams [9]. Because of the coal seam roof strata combination characteristics, rock mechanics properties, geological structure conditions and the methods of mining are different, the mining face, coal seam, support the affected zone, overburden bed separation grouting to compaction the distribution scope are different. In addition, the caving zone and the status of the fracture zone are also different.

On the basis of fully studying the main flow patterns of gas in the coal seam and the migration rules followed, combining with the measurement technology of the current gas concentration, gas pressure, the physical parameter under the mine is measured electrically and the device is designed and developed. The device can realize the flow, concentration, negative pressure and temperature test of any single hole or pore group in the borehole, and also check the accuracy of the commonly used gas comprehensive parameter measuring instrument in the field. To solve the uninstalled diversion pipe of the single hole or part of the hole in the coal mine which are unable to measure the parameters such as flow rate, concentration test, to ensure the comprehensiveness, accuracy and reliability of the extraction parameters test. Monitoring extraction important basic parameters of drilling operation on the ground, to evaluate the efficacy of the borehole extraction in time and further make the correct adjustment, eventually the purpose of improving the gas extraction rate and utilization rate is achieved.

The optimization of gas drilling and drainage technology is of great significance to increase gas extraction rate, reduce gas emission, increase enterprise capacity, prevent gas content from exceeding the specified range in working face and ensure safe production [6] ,the purpose of this is to build a large database for the construction

of the mine in the future, so as to prepare for the machine learning and intelligent management of mine operation information.

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