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Radon Measuring to Detect Coal Spontaneous Combustion Fire Source at Bulianta Mine, Shendong

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ABSTRACT: The paper introduces the theory of using radon to detect the source of coal fires resulting from spontaneous combustion and its successful application at the No.12405 gob area in Bulianta Mine, Shendong. The practice shows that this method provides the scientific basis for coal seam spontaneous combustion control plan-making. It is a key technology and can be applicable for wide applications.

INTRODUCTION

Coal spontaneous combustion fires can be a kind of significant disaster for coalmines. The prediction of spontaneous combustion and fire source detection are the most critical techniques. The location where the spontaneous fire happens can be several hundred meters underground, this makes the fire source elusive and hard to be approached. Therefore, the technology of how to detect the exact fire source becomes more important for underground fire extinguishment. This is also a world-wide problem (Zhang, 2008; Wu, 2008). Taiyuan University of Technology (TUT) invented a system to detect the location of the spontaneous fire source by measuring radon. Using radon as a carrier, this system can not only detect the location and the range of the fire source, but also predict the trend of fire behavior and the changing status of the underground fire. The system has the advantages of easy operation, less cost, anti-jamming and fast reaction speed. Input of the detected data into the Radon Measuring and Fire Detecting Data Processing System (CDTH) can indicate the spontaneous combustion fire location, the fire area and the fire behavior. Compared with similar technology at home and abroad, the practice showed that it is more accurate (fire centre 90% precision, and 85% for the fire edge) and can detect down to 800 m in depth. The radon measuring method has been successfully used at coal mining areas in China and Australia and it is the only practical technology for underground coal spontaneous fire source detection (Wang, 2010; Jia, *et al.*, 2002; Zhao and Wu, 2002).

THE BULIANTA MINE AND THE FIRE ZONE

Bulianta mine is the biggest underground mine in the world. Built and operated by Shendong Coal Group, it is located at Ordos Inner mogonlia with 106.43 km^2 of mining area, 1 550 Mt of mineable reserve and 77 years of service life. The major coal seams are $No.1^{-2}$, $No.2^{-2}$ and $No.3^{-1}$. The total production reached 25 Mt in 2010.

On 13th November 2011, at the transport gateroad of No.12 405 working face, CO was found over limit from the observation hole of the permanent anti-fire wall. The CO data went up to 900 ppm on 16^{th}. The CO detection of the crosscut at No.12 406 working face reached 200 ppm and the data at the crack on the coal rib reached 2 000 ppm. The dangerous gases like ethane (C_2H_6), ethylene (C_2H_4) and ethyne (C_2H_2) were also detected. Preliminary analysis showed that spontaneous fire happened at the gob area near the main return of No.12 405 working face. It is very dangerous to the coalmine safety. The coal mine adopted all the fire combat measures they could such as surface grouting, nitrogen injection, thick mortar injection, pressure equalising for No.12 406 working face, ground sealing and ground borehole casting. But the fire could not been totally controlled from the evidence of the gas analysis. In order to find the exact location of the spontaneous fire source, TUT conducted a fire source detection from 17^{th} to 23^{rd} Nov, 2011. The total investigation area is about 120 000 m^2 and 609 surface detection points were used. Data collected from these points provided the scientific basis for the fire fighting work for the coalmine.

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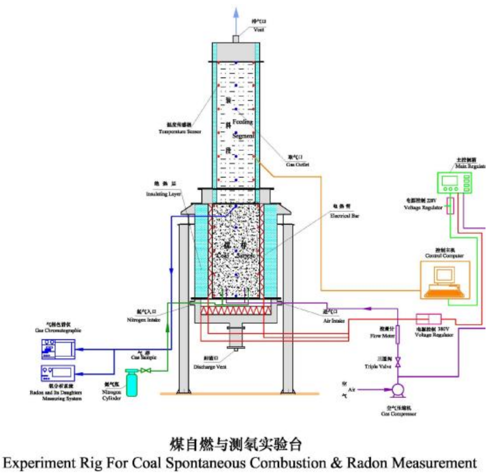
DETECTION METHODS

Detection theory

Radon is naturally existing within the coal rock and it is radioactive. Along with the rising temperature, the radon gas evolution will also increase. Based on this mechanism, the "Surface Radon Measuring Method" has been invented to detect the spontaneous fire source location. Detecting the radon variation from the surface, the fire source location, fire range and the fire behavior trend can be found through data processing. A research team from TUT used the large-scale experimental rig of coal spontaneous and radon measurement to study the variation behaviour of radon from coal sample, the radon gas evolution goes up when the temperature rises (Zhao and Wu, 2003; Xue, *et al.*, 2008).

Figure 1 shows the structure of the experimental rig for coal spontaneous combustion and radon measurement. The device is located at the fire disaster laboratory of China-Australia Mine in TUT. It is used for radon research when coal spontaneous combustion happens.



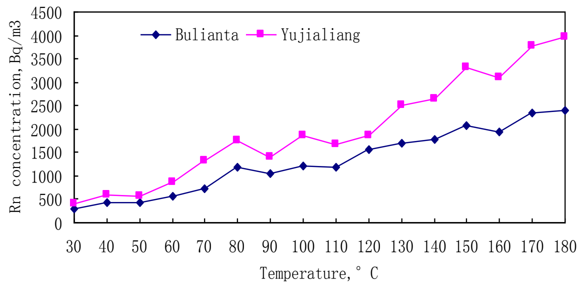


Figure 1 - The structure of the experiment   **Figure 2 - Rn concentration with coal temperature**

There are three radioactive series widely existing in nature, they are the uranium series, thorium series and actinium series. They can exist in the rock, soil and coal as parent nuclide because of their longer radioactive half-life. Through a series of disintegration, uranium, thorium and actinium produce the radioactive nuclide radon and it can exist under normal pressure and temperature as aerosol. For its longest half-life period, the radon is taken as a carrier to research the earth dynamic phenomenon. The radon here mainly refers to the decay daughter of the uranium, Rn-222, and its own decay daughter.

Like the radioactive isotope radon, its decay daughter is a solid particle, so both radon gas and its decay daughter can reflect the shape and the variation of the parent nuclide. Radon daughter has a very strong adsorptive capability. It can stick at the surface of the container. Many options are available to collect radon and its daughter for measuring (Wu, *et al.*, 2004; Xue, *et al.,* 2010; Zhou, *et al.,* 2003).

Detection method

There are many methods to measure radon. From timing measuring, there are differentiation and integration methods. According to the instrument being used, there are the α cup method, active carbon method, thermo-luminescence method and polonium 210 method. For this experiment, α cup with integration method was adopted (Xue, *et al*., 2003; Xue, *et al.*, 2004).

Instrument and process

The high sensitivity, the CD-1α cup radon measuring instrument, was selected for the experiment. It is handy and easy to operate. It has an ion type detector and after the radon daughter is ionised, the Count Per Minute (CPM) will be displayed. Timing includes 1 min, 3 min, and 5 min, normally 3 min is chosen. The disadvantage of this device is that is not shockproof. The matched α cup has about a 12×8 cm^2 detection area and it is made of highly adsorptive material for easier radon adsorption.

The detection cup was buried at the pre-selected spots with the spacing of 15 m×15 m, the spacing could be 20 m×20 m, 15 m×15 m or 10 m×10 m, depending on site conditions. The cup was put bottom up in the 40～50 cm pit with plastic cloth covering as show in Figure 4. Four hours later, the cup is taken out and immediately put into the instrument for measuring, set timing at 3 min and recorded the data. If the data showed anything unusual and the need for more measuring spots for proving, more could be added at anytime.

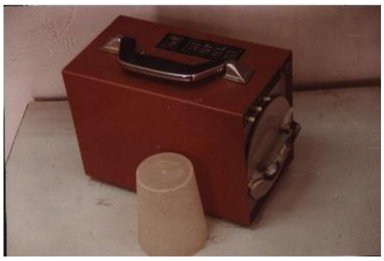


Figure 3 - Field radon measuring instrument

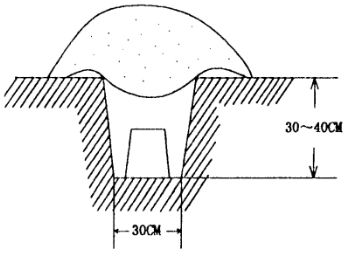


Figure 4 - Detection point and collection cup

Detection area arrangement

According to the field conditions, the Bulianta Mine fixed the boundary of the detection area, about 120 000 m^2, in which 609 detection points were arranged with the spacing of 15 ×15 m as shown in Figure 5

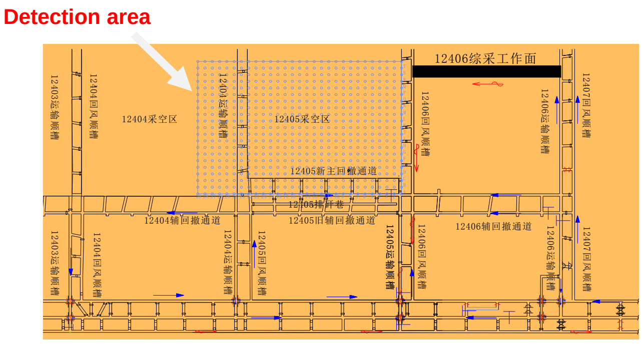


Figure 5 - The arrangement of spontaneous fire source detection at the gob area of N.12 405 working face at Bulianta Mine, Shendong

DETECTION RESULT AND ANALYSIS

The collected data from the field was then processed using the CDTH software package, Figures 6, 7, 8, and 9 respectively illustrate an actual data block diagram and its contour map and an unusual data block diagram and its contour map.

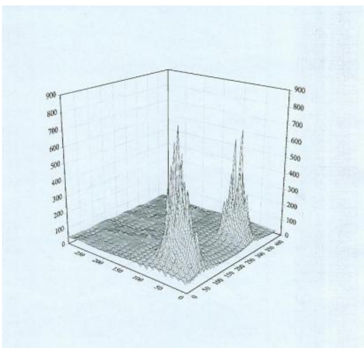


Figure 6 - Actual data block diagram

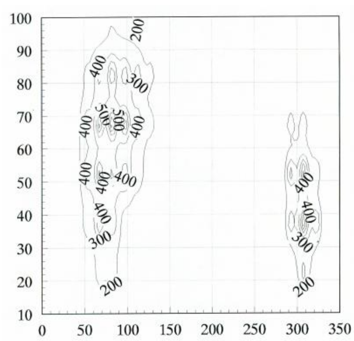
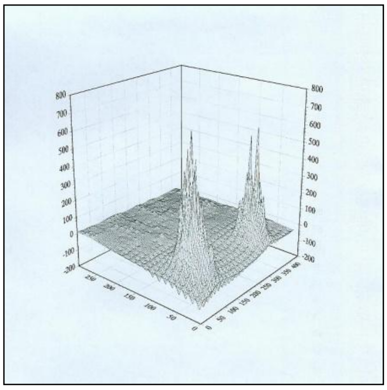


Figure 7 - Actual data contour map



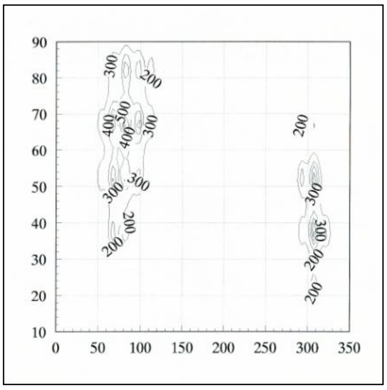


Figure 8 - Unusual data block diagram **Figure 9 - Unusual data contour map**

From the above analysis, the plan view of the spontaneous combustion fire source location detection at the goaf area of N.12405 working face at Bulianta mine, Shendong.was obtained and is shown in Figure 10.

Figure 10 - Plan View of the spontaneous combustion fire source location detection at the goaf area of N.12 405 working face at Bulianta Mine, Shendong

Result analysis

1. Two districts were found with unusual detected data; they were district A and district B with a total area of 2010 m^2.
2. District A is a high temperature oxidising zone. It is located at the No.4 crosscut of the main return at the No.12 405 working face with 569 m^2 area. District B is also a high temperature oxidizing zone. It is at the No.5 crosscut of the No.12 404 transport gateroad.
3. The extent, the location and the development trend of these two districts with unusual data were shown on the plan view of the spontaneous combustion fire source location detection at the goaf area of N.12 405 working face at Bulianta Mine, Shendong.

APPLICATION IMPACT

According to the detection, the boreholes were drilled at the corresponding position from the surface. The bottom temperature of the borehole was measured, it was 50～150^{o}C. A gas sample from the borehole bottom was collected and subsequently analysed using a GC, which showed that the 10% of CO concentration along with the C_2H_2, C_2H_4 measured gas. It indicated that the location of the high temperature zone is corresponding to the reality of a fire.

After the fire source location was identified, the Bulianta Mine drilled boreholes to the high temperature zone and injected cement for extinguishment: First, a vertical borehole from the surface was drilled, then based on the unequal fire zone, boreholes were drilled evenly along the major axis and minor axis. Secondly, grout was injected to fire zone from boreholes. To avoid the fire zone spreading, drilling and grouting were also conducted along the edge of the fire zone. At the same time, the coal mine also took measures from underground, like sealing, grouting and stopping leakage. Then samples were taken to analyse the gas taken from the fire zone (Figure 11), fifteen days later, it showed that the symbolising gas concentration, CO, C_2H_2, $C_2H_4$and C_2H_6 , were significantly lower. This indicated that the measure the mine taken had worked effectively.

According to the research result of the TUT team, the Bulianta Mine conducted drilling and grouting with clear goals, this not only improved the extinguishing effective, but also saved the material and manpower from blind drilling and grouting. The application of the radon measuring method was very successful with wonderful effect.

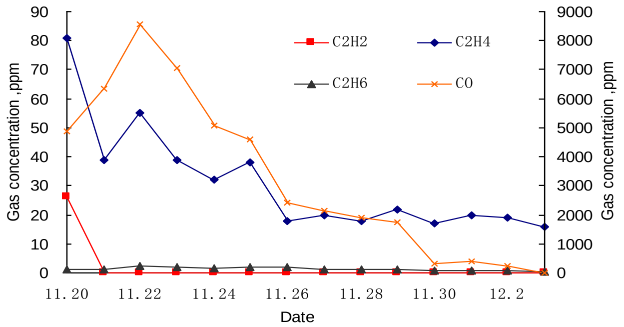


Figure 11 - Variation tendency chart of measured gas from the gateroad of the No.12403, Bulianta

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