Comprehensive prevention and control of coal and gas outburst in south second well of Liziya coal mine

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Abstract. Based on the analysis of the present situation and existing problems of coal and gas outburst in the second South well of Liziya coal mine, and adhering to the concept of comprehensive gas control, the field test and design of the main mining K₁ coal seam are carried out respectively from the outburst prevention prediction sensitive index and critical value, regional outburst prevention measures, hydraulic fracturing permeability enhancement measures and local outburst prevention measures. The critical value of outburst prevention prediction sensitive index in the test area is: $k_{im} = 0.40 \text{ Ml/g \cdot Min}^{1/2}$, $S_m = 4.3 \text{ kg/m}$; in the production area, the bottom rock pre drainage tunnel through layer drilling pre drainage, the coal tunnel through layer strip pre drainage, the double tunnel layout drilling pre drainage are used to improve the gas drainage rate by hydraulic fracturing and permeability enhancement measures, fundamentally eliminate the risk of coal and gas outburst, and realize the safe production of the mine.

1. Introduction

The main coal seam in South Second Well of Liziya Coal Mine is the K₁ coal seam located in the middle of the second sub-segment of the first segment (P2I) of Longtan Formation. The total thickness of the coal seam is 0.09~4.37m, with an average of 2.18m. Coal seam gas pressure is 3.4MPa; gas content is $19.41 \text{ m}^3/\text{t}$; permeability coefficient is $0.902\sim1.7\times10^{-2}\text{ (Mpa}^2/\text{d)}$; borehole gas emission attenuation coefficient is $0.3137\sim0.9283\text{d}^{-1}$; coal sample The coefficient of firmness is $0.2\sim0.29$; the initial gas velocity of coal sample is $8\sim23$; the porosity of coal sample is $2.94\sim5.67$%; the adsorption constant of coal sample is $a=20.67\sim24.8467\text{m}^3/\text{t}$, $b=0.844\sim1.2852\text{ MPa}^{-1}$. The 2009 gas grade identification results are: the absolute gas emission of the mine is $16.32\text{ m}^3/\text{min}$, the absolute emission of carbon dioxide is $2.63\text{ m}^3/\text{min}$, and the mine is a coal and gas outburst mine.

2. Status and problems of coal and gas outburst

Since the construction of the second well of Liziya Coal Mine, There were 12 coal and gas outburst accidents, 10 occurrences in 3102 machine lanes and 2 occurrences in 3102 wind lanes. The main types of coal and gas outbursts are caused by blasting. It can be seen that the blasting stress redistributes the stress of the coal tunnel driving face, which produces local stress concentration and exceeds the
resistance of the coal rock body to destruction. Eventually under the combined action of in-situ stress (including tectonic stress) and high pressure coal seam gas pressure, etc. Coal and gas outburst occurred. The prediction indexes measured before the outburst: the amount of cuttings $S_{\text{max}}=5.7\, \text{Kg/m}$, the index of gas desorption of cuttings $K_{1\text{max}}=0.42\, \text{mL/g} \cdot \text{min}^{1/2}$, $\Delta h_{2\text{max}}=22\, \text{mmH}_{2}\text{O}$. The measured value of the forecast index has exceeded the critical values $S_m$ and $\Delta h_{2m}$ of the forecast index implemented at the time at the mine (the critical index values implemented at that time were: $S_m=4.8\, \text{Kg/m}$, $K_{1m}=0.5\, \text{mL/g} \cdot \text{min}^{1/2}$, $\Delta h_{2m}=20\, \text{mmH}_{2}\text{O}$), from the perspective of the forecast index value before highlighting, the lack of reliability in defining the critical value of the forecast index has led to the limitation of the evaluation system of the anti-outburst measures, which is the reason for the technical management of leading accidents. The coal roadway in the first mining face of 3102 is located near the axis of the east wing of the Longwangdong anticline, and the coal seam gas is not easy to release. Most of the outburst points are located in the geological structural change zone of the coal seam. The coal seam is affected by the rubbing, which causes the coal seam to disappear, the coal seam is disordered and loose, and the hardness is uneven, resulting in difficulty in support. In addition, the thickness of the coal seam changes greatly before and after the outburst point. The coal seam is affected by in-situ stress, and the sliding fluidity between the coal seams becomes thinner and thicker, resulting in soft coal seams and disordered coal seams. From the above analysis, it can be seen that the K1 coal seam in the first mining face 3102 of Liziya South Second Well has all kinds of objective conditions for coal and gas outburst, and for the serious outburst coal seam, the coal bed gas geological occurrence conditions are the root cause of outburst occurrence [2].

3. Comprehensive prevention technology of coal and gas outburst

Aiming at the situation of the K1 coal seam in the second well of Liziya South, the sensitive indicators and critical values of outburst prediction in the tunneling face were determined through experimental investigations, and through the examination of the effects of coal roadway excavation and outburst prevention measures, a prevention and control system and management system suitable for the coal and gas outburst of the mine are formed to provide a reasonable guarantee for the safe production of the mine.

3.1. Determine the sensitive index and critical value of the test area

Research on the critical value of the sensitive index of working face prediction usually adopts comprehensive analysis methods such as theoretical analysis, laboratory testing, on-site inspection, and outstanding characteristics and laws for preliminary determination, and is finally determined after certain engineering verification. and then in similar gas geology, mining Popularize and apply under technical conditions. The prediction of drill cuttings volume S and gas desorption index $K_1$ was carried out in 3102 South Machine Lane. The test results are shown in Fig. 1 and Fig.2.

![Figure 1. S curve of drill cuttings volume in 3102 South Machine Lane.](image)
As can be seen from Fig. 1, under normal circumstances, the average value of the amount of cuttings $S$ changes along the drilling direction is small, basically a gentle straight line, and increases with the increase of the drilling depth, the amount of cuttings and the drilling depth $A$ linear proportional relationship. Under abnormal conditions, the amount of drill cuttings increases rapidly with the depth, the curve changes greatly, and anomalies appear during the drilling process.

It can be seen from Fig. 2 that the measured value of the drill cuttings desorption index is larger, and the measured value of abnormal conditions is significantly increased than the normal condition. The predicted average increase rate of every 2m along the depth of the hole is $31\%\sim 308\%$. The coal sample has lower hardness, higher gas content, and greater gas desorption and emission capabilities. The field test desorption index $K_1$ is also relatively large. In this case, the coal seam generally has the danger of gas outburst and the tendency to outburst is great.

During the drilling process, when $S>4.3\, \text{kg/m}$ or $K_1>0.40 \, \text{mL/g.min}^{1/2}$, the phenomenon of stuck pipe and suction drill began to appear, and with the increase of the predicted index $S$ and $K_1$ value, stuck pipe appeared, the more times of suction drilling, the more obvious the phenomenon. The predicted index value before multiple outbursts that have occurred in the mine is $S>4.3\, \text{kg/m}$ or $K_1>0.40 \, \text{mL/g.min}^{1/2}$. So the critical value of the index should not be greater than this value. When the coal seam conditions are stable, the economic and safety principles of the forecast index are considered, and the $S$ and $K_1$ values of the forecast index can be appropriately increased. In summary, it is determined that the prediction sensitive index and its critical value of the K1 coal seam test area in South Second Well of Liziya Coal Mine are: $K_1 \geq 4.0 \, \text{mL/g.min}^{1/2}$, there is a risk of outburst, and $S \geq 4.3\, \text{kg/m}$, there is a risk of outburst.

### 3.2. Anti-outburst technology for coal tunnel driving

In the second well of Liziya South, coal and gas outburst occurred in the process of coal roadway excavation, which brought unavoidable hidden dangers to the safety production of the mine. Therefore, during the coal roadway excavation operation activities, the disasters caused by gas should be highly valued. The mine should adhere to the concept of comprehensive gas control, focus on the outstanding prevention and control during the excavation process, and adhere to the principle of taking regional measures as the main and local measures as the supplement. The regional anti-outburst work should be multi-pronged, exhaustive and effective. For the coal tunnel driving face without outburst danger, the tunneling operation must be carried out under the conditions of taking safety protection measures and retaining enough outburst prediction lead distance and anti-outburst measures.

#### 3.2.1. Regional anti-outburst measures

According to the "Regulations on Prevention of Coal and Gas Outburst", before coal roadway in dangerous areas, regional outburst measures should be taken to eliminate or reduce the outburst danger. Regional outburst measures mainly include pre-draining coal seam gas and mining protection Floor. The K1 coal seam in the second well of Liziya South is mined...
by a single coal seam, and there are no protective seam mining conditions. Therefore, the regional outburst prevention measure of the mine is pre-draining coal seam gas.

(1) Layout of drilling holes for driving face

According to the development layout of the second well in Liziya South, the rock drainage roadway was first constructed on the bottom plate of the K1 coal seam before coal roadway driving. Then the coal roadway driving face mainly used penetration drilling to extract and drill coal seam gas within the coal roadway strip. The control range of the hole is: along the coal seam roadway contour along the striking coal seam is more than 20m above and below 10; on both sides of the coal seam roadway along the inclined coal seam is 15m on both sides, the pre-drainage drilling through the layer is flat and the schematic diagram is shown in Fig. 3 and Fig. 4.

![Figure 3](image1)

**Figure 3.** Layout plan of pre-drainage drilling holes in coal tunnel crossing strips.

![Figure 4](image2)

**Figure 4.** Layout section of pre-drainage drilling holes in coal tunnel crossing strips.

(2) Drilling hole layout in working face

The drilling holes in the mining layer are mainly inclined drilling along the layer, drilling along the stratum along the stratum, and gas drainage lanes for the coal seam floor. Considering the instability of part of the coal seam in the mine, the slope fluctuates greatly along the inclination direction, and it is difficult to realize the extraction and drilling of the coal seam through the entire working face only in the coal seam transportation lane. In order to improve the extraction efficiency and facilitate the construction, in the block with unstable coal seam inclination, this design adopts double lanes (transportation lanes and return air lanes) to arrange borehole extraction. Considering that the mining stress affects the concentrated area at the cutting face of the advanced working face of about 8-10m, the drill hole will lead to the leakage of coal seam cracks at the final hole position and the mining stress affect the concentrated area, so the cutting face of the advanced working face is opened or stop mining at about 10m from Shimen. details as follows:
Double-lane layout borehole extraction: Use the transportation lanes and return air lanes in the face to arrange the extraction boreholes, and install the extraction pipeline for gas extraction. The following indexes can be adopted for the drilling interval and drilling diameter: the upward hole is 90m deep, and the downward hole is 60m deep (if the drilling on one side cannot reach the design depth, the drilling length on the other side should be extended, and drilling on both sides should cover the entire working face together), the distance between the opening and the final hole is 1.6m, the hole diameter is 94mm, and it is arranged in a single row along the inclined direction of the coal seam (double-row cross-drilled holes can be arranged where the coal thickness exceeds 3m). The angle of incision is 5° toward the working surface.

**Figure 5.** Schematic diagram of the layout of drainage holes in the inclined double layer.

Gas drainage roadway for floor: if the outburst removal time of the drilling along the stratum of the working face is long, the mining excavation replacement is tense or the predrainage outburst effect of the drilling along the stratum is not good, the wear can be added before the mining face. The method of drilling and extracting coal seam gas in the section of the working face of the stratum to improve the regional outburst effect and reduce the time required for outburst. Through-hole drilling control except for the return air lanes, transportation lanes in the working face and cut-out drilling in the coal seam of the entire mining area, the drilling should use grid-dense drilling. Depending on the degree of excavation succession, the mine takes 4~8m. If the drilling hole in the bedding area of the working face has poor outburst removal effect or the excavation succession is tight, the smaller distance is adopted; otherwise, the larger distance is adopted. The schematic diagram of the borehole layout for supplementing the coal seam gas in the working face area through the cross-hole drilling is shown in Fig.6.

**Figure 6.** Schematic diagram of the layout of the pre-draining coal seam gas drilling in the bottom-hole drilling.

Borehole layout of Shimen coal mining: When the second well of Liziya South broke through the outburst coal seam in Shimen, the excavation of the Shimen working face was 7m away from the coal seam vertical distance, and the regional anti-outburst measures for coal gas in the coal mining area were taken. The borehole must penetrate the top (bottom) plate of the coal seam by more than 0.5m.
According to the "Regulations on Prevention of Coal and Gas Outburst", the minimum control range for drilling holes in the Shimen coal mining area is: 12m outside the contour of the roadway in the coal mining area of Shimen and vertical shafts and inclined shafts (the bottom or bottom of the steeply inclined coal seam is 6m), At the same time, the minimum distance from the outer edge of the control range to the roadway outline (including the outline of the roadway in front of the exposed coal section) should not be less than 5m, and when the borehole cannot penetrate the full thickness of the coal seam at one time, the coal hole should be kept to a minimum. The lead distance is 15m. Schematic diagram of the layout of Shimen extraction drilling is shown in Fig.7.

![Diagram](image1)

**Figure 7.** Schematic diagram of Shimen extraction drilling borehole arrangement.

(3) Hydraulic fracturing and permeability enhancement measures

1# water injection fracturing borehole was constructed at the horizontal distance of +520 north drainage roadway from the slope opening at 50m. The azimuth angle of the borehole is 128°, that is, the angle between the fracturing borehole and the axis of the tunnel is 90°, the inclination angle is about 45°, the total length of the fracturing borehole is 19.5m, and the final hole is located at 3102 North machine Lane. The layout of water injection and fracturing drill holes is shown in Fig. 8 and Fig. 9. In addition, a row of observation holes was constructed as a fracturing observation hole 50m from the south side of the water injection hole, and a pressure measurement borehole was located 100m from the north side.

![Diagram](image2)

**Figure 8.** Schematic diagram of Shimen extraction drilling borehole arrangement.

![Diagram](image3)

**Figure 9.** Schematic diagram of Shimen extraction drilling borehole arrangement.

Before the fracturing, the amount of gas emitted from the borehole was measured. During a 7-day period, a total of 3.4075 m$^3$ of self-discharged gas (reading when the self-discharged gas meter was stationary) was averaged, with an average of 0.00034 m$^3$/min. After pre-cracking of high-pressure water, the maximum self-drainage gas flow rate of the borehole is 0.524 m$^3$/min, and the average self-drainage gas flow rate of the borehole is 0.036 m$^3$/min. The average gas flow rate of the drilled hole without hydraulic pre-cracking under similar conditions was 0.005 m$^3$/min. After the implementation of hydraulic pre-cracking measures, the self-drainage flow rate of the borehole gas increased by 6.2 times.
The single medium-thick coal seam through-hole drilling has a 94.4-fold increase in the self-drainage flow rate of the discharged borehole without hydraulic pre-cracking. Judging from the changes in the gas flow rate of the borehole, the hydraulic pre-cracking effect is very good. During the water injection, there is water gushing from the detection hole 50m away, and it can be preliminarily concluded that the influence radius of the hydraulic pre-crack has reached 50m.

The residual gas pressure and residual gas content are the main indicators for testing the gas drainage effect. When the coal seam gas content or pressure at the initiation depth of the coal seam is not investigated, the coal seam residual gas content must be reduced to below 8m³/t, or the coal seam residual gas pressure drops below 0.74MPa (gage pressure). When the residual gas pressure and residual gas content reach the standard, it is still necessary to use the method of face prediction in the coal roadway driving face and coal mining face to perform regional verification on the non-outburst danger area. The area verification should meet: at least two consecutive area verifications are carried out immediately when the working face enters the area; at least two area verifications are carried out for every 10-50m advancement of the working face; the area verification is continuously carried out in the structural destruction zone; The surface should also be drilled with at least one advance borehole with an advance distance of not less than 10m or take advanced geophysical measures to detect geological structures and observe outbursts. When the area is verified to have no outstanding danger, safety protection measures shall be taken before the excavation operation. However, if it is the first regional verification carried out in this area for the mining face, sufficient protruding prediction lead distance should be retained before mining. As long as an area is verified as having an outburst danger or an outburst has been discovered, a future anti-outburst measure should be implemented for future mining operations in the area.

3.2.2. Local anti-outburst measures. (1) Outstanding risk prediction

The outburst prediction method of the K1 coal seam driving face in the second well of Liziya South Well adopts the drilling chip gas desorption method specified in Article 75 of the "Regulations on Prevention of Coal and Gas Outburst". The outburst prediction index adopts the K₁ value of drill cutting gas desorption index and the amount of drilling powder S, and the K₁ value prediction instrument adopts the WTC gas outburst danger parameter meter. It is predicted that the hole will be drilled in layers along the soft coal, keeping the drilling speed at about 1m/min. During the drilling process of each borehole, starting from the 2m, the amount of drill cuttings S is measured every 1m, and the K₁ value of the gas desorption index of the cuttings is measured every 2m. According to the predicted maximum drill cuttings S and the maximum K₁ value, it is predicted that the excavation face will highlight the danger. Three predictive drill holes are arranged in the coal tunnel driving working face, with a hole depth of 8-10m and an aperture diameter of 42mm; one of the drill holes is arranged in the middle of the working face and is consistent with the driving direction, and the other two drill holes are separated from the two gangs by 0.5 m, the final hole is 2~4m outside the roadway outline, and the predicted drill hole layout is shown in Fig. 10.

![Figure 10. Schematic diagram of the predicted drilling layout in the coal roadway driving face.](image-url)

According to the comparison between the prediction result and the prediction sensitive index and its critical value, the result is a working face without protruding danger, and the tunneling distance is taken under the premise of taking safety precautions. The allowable tunneling distance is the projection length
of the tunnel in the tunnel tunneling direction minus with the shortest predicted borehole go to 2m, which means that the predicted safety lead distance is 2m. After excavation is in place, the outburst danger prediction is made; the result shows that there is a outburst danger face, and local outburst prevention measures must be taken. Only under the condition that the local anti-outburst measures are checked and valid, under the premise of taking safety protection measures and at the same time ensuring a certain predicted lead distance and measures before the lead distance, the digging operation can be carried out.

(2) Anti-outburst measures for tunneling face

The local outburst prevention measures mainly added pressure relief boreholes at the bottom and middle of the coal seam tunneling face, and considering the construction progress on site, a large-diameter borehole discharge method was adopted, that is, the high-pressure gas in the coal body in front of the discharge tunnel face was discharged At the same time, the in-situ stress of the coal body is released through large-diameter drilling, so as to achieve the purpose of effectively eliminating outburst. The control range of large-diameter drilling is 15m on the upper side of the roadway and 5m on the lower side, 40m in front of the working face, and the effective spacing of the bottom of the hole is 3m.

Figure 11. Schematic diagram of large-diameter drilling layout.

Figure 12. Schematic diagram of large-diameter drilling location.

The drill holes should be evenly arranged within the control range, and the number of drill holes can be appropriately increased in the soft layering of the coal seam. Before drilling, the support of the working face should be strengthened. If the drilling diameter exceeds 120mm, special drilling equipment and special construction safety measures must be developed.
4. Conclusion

(1) The critical value of the sensitive index determined by the study in the test area is: $K_{1m}=0.40 \text{ mL/g·min}^{1/2}$, $S_m=4.3 \text{ kg/m}$.

(2) Large-diameter borehole outburst prevention measures are used as local outburst prevention measures in the coal roadway driving face of the south second well of Liziya, the control range of large-diameter boreholes is 15m for the upper side of the roadway and 5m for the lower side. The effective spacing of the hole bottom is 3m. The drill holes should be evenly arranged within the control range, and the number of drill holes can be appropriately increased in the soft layering of the coal seam.

(3) Based on the site inspection of the first hydraulic pre-fracturing borehole, the effect of hydraulic fracturing and drainage gas can be preliminarily obtained: hydraulic pre-fracturing affects a radius of 50m, the permeability of the coal seam in the affected area is greatly increased, and the borehole gas flow increased flow. Judging from the changes in the gas flow rate of the borehole, hydraulic pre-cracking is very obvious to improve the gas drainage effect.

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