

Research on the Mining Practice of Protection Layer in the Complex Geological Conditions of Qidong Coal Mine

Xingang Niu *

National Key Laboratory of Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing, China.
Chongqing Research Institute of China Coal Technology & Engineering Group, Chongqing, China.

*Corresponding author e-mail: 1197807770@qq.com

Abstract. To study the effect of 8_2 coal seam unloading and outburst prevention with 7_1 coal seam mining, as well as the influence of the integrated application of research methods of theoretical analysis and field practice, the feasibility of the protective layer under the condition of mining research, and in the process of 7_1 coal seam mining, below 8_2 coal seam gas content, gas pressure and the effect of the deformation of coal unloading field measurement and comprehensive theoretical analysis. The research results show that the protective layer of 7_1 coal seam as the lower 8_2 coal mining is feasible in theory, in 7_137 working face of the actual mining process, the lower 8_2 significant increase in the permeability of coal seam, the gas content is greatly reduced, unloading deformation effect is obvious, further verify the three 7_1 coal seam as the lower protective layer of 8_2 coal mining, the discharge pressure and outburst prevention with dual effectiveness, to ensure safe and efficient mining of coal seam 8_2 .

Key words: Upper protective layer mining; Pressure relief effect; close distance coal seams.

1. Introduction

The research shows that the protective layer mining is the most effective and economical regional comprehensive countermeasure at present [1-3]. In the process of protective layer mining, the relation between protective layer and protected layer can be divided into upper protective layer mining and lower protective layer mining. For the mining of upper protective layer, predecessors have carried out in-depth research [4-9]: liu zhen et al. have done relevant research on the gas treatment technology of the protective layer mining on the close outburst coal seam group; Wang haifeng et al. carried out some research on the gas emission rule of the protective layer mining face at close range, and on the basis of this, optimized the pressure relief gas extraction parameters of the protective layer, and all the above studies have obtained some meaningful conclusions. However, there are few studies on the mining of multiple protective layers in the mining process of coal seams. On the basis of previous research and according to the practical situation of qidong coal mine project, this paper conducts a detailed



investigation and analysis of the effect of overlying 6₁ and 7₁ coal seam mining on the pressure relief of 8₂ coal seam by combining theoretical analysis and field practice.

2. Geological Survey

The Qidong coal mine mainly mines 3₂, 6₁, 7₁, 8₂ and 9 coal seams, all of which are coal and gas outburst coal seam. The interval between layers of the central coal group 6₁, 7₁ and 8₂ in the third mining area is 40.17m and 30.19m respectively. Because the 6₁ coal seam of this mining area is located in the area without the danger of coal and gas outburst, it is used as the protective layer of the first mining of the underlying 7₁ and 8₂ coal seam, and then the 7₁ coal seam is used as the protective layer of the 8₂ coal seam. Since 6₁ coal seam has been mined, this paper mainly studies the protective effect of 7₁ coal seam mining on 8₂ coal seam on the basis of the first mining protective layer.

Test the average coal 7₁37 working face of thick 3.3 m, average 13 ° Angle. Below the working face is the unmined 8₂ coal seam, the normal distance is about 30m. The working face adopts the coal mining method of long wall retreating and comprehensive mechanization with full mining height in one time, and the roof is managed by the whole span method. 8₂ average coal seam thickness of 1.85 m, an average of 13 ° Angle.

Based on the 7₁37 working face as test protective layer of working face, The working face average coal seam thickness of 3.3m, average Angle of 13°. Below the working face is the unmined 8₂ coal seam, the normal distance is about 30m. The working face adopts the coal mining method of long wall retreating and comprehensive mechanization with full mining height in one time, and the roof is managed by the whole span method. Average 8₂ coal seam thickness of 1.85m, average Angle of 13°.

3. Downgoing Mining Feasibility Judgment

The spacing between the working face of 7₁37 protective layer and the underlying 8₂ coal seam is 28~32m, with an average of 30m. Referring to the technical manual for coal mine gas disaster prevention and utilization (revised edition) [11] and combining the domestic mining experience of upper protective layer, it can meet the requirement of effective layer spacing on inclined protective layer when it is not pumped out. Therefore, it is considered that the mining of 7₁ coal seam is effective for the pressure relief protection and regional anti-outburst measures of 8₂ coal seam, which is technically feasible.

At the same time, the average mining height of 7₁37 protective working face is 3.3m, which meets the requirement that the minimum mining thickness of protective working face stipulated in article 46 of coal and gas outburst prevention and control regulation is more than 0.5m.

The maximum protection sag of the upper protective layer to the lower protective layer shall be determined by reference to appendix D.3 of the regulations on coal and gas outburst prevention.

As the 7₁ coal seam in the test area is a gentle inclined coal seam, the maximum protection sag of upper protective layer mining (gentle inclination and inclination) is less than 50m, referring to the table D.2 in appendix D.3 of the regulations on coal and gas outburst prevention and control.

$$S_{up} = S'_{up} \times \beta_1 \times \beta_2 \quad (1)$$

Type : S'_{up} —The theoretical maximum protection sag of the upper protective layer, m.

It is related to working face length L and mining depth H, and can be taken as reference to table D.3 in appendix D.3 of coal and gas outburst regulation. When $L > 0.3h$, $L = 0.3h$, but L should not be greater than 250m.

β_1 —Influence factor of protective layer mining.

When $M \leq M_0$, $\beta_1 = M/M_0$; when $M > M_0$, $\beta_1 = 1$.

M—The mining thickness of the protective layer, m.

M_0 —Minimum effective thickness of protective layer, m.

M_0 can be determined by reference to FIG. D.3 in appendix D.3 of coal and gas outburst prevention regulations. (under this condition, $M_0 = 0.6m$)

β_2 —Interlayer hard rock (sandstone, limestone) content coefficient.

As η percentage of the rock between layers, When $\eta \geq 50\%$, $\beta_2 = 1 - 0.4\eta/100$, and when $\eta < 50\%$, $\beta_2 = 1$. (under this condition, $\eta = 94.76\%$)

By substituting each parameter into equation (1), it can be calculated that the maximum effective protective sag of the underlying 8_2 seam by mining of 7_1 coal seam is about 36.64m. Because the spacing between the working face of the protective layer of 7_1 and the underlying seam of 8_2 is 28~32m, less than the general maximum protective vertical, it is considered that the mining of 7_1 coal seam as the protective layer of the underlying seam of 8_2 is feasible in theory.

4. Analysis of Impact of Downgoing Mining on Protected Coal Seam

4.1. Measurement of Gas Parameters in Protected Area of Coal Seam

4.1.1. Original Gas Pressure Measurement of Protected Coal Seam 8_2 . The original gas pressure of the 8_2 coal seam was measured before the mining of the 7_1 protective working face. The gas pressure was measured by direct method, mechanical grouting sealing hole and passive pressure measurement. According to the development preparation of Qidong coal mine and the roadway layout conditions, the pressure measurement site is arranged in the no.1 gas extraction roadway of the east wing of the third mining area, all of which are downward piercing boreholes. Moreover, before the pressure measurement borehole, the perforated gas extraction borehole of 8_2 coal seam has not been constructed. A gas pressure measuring point of 8_2 coal seam (two boreholes in total) is arranged in the no.1 gas extraction roadway of east wing of the third mining area within the theoretical protection range of 7_1 protective layer working face. The construction parameters and test results of borehole are shown in table 1.

According to the requirements of the direct measurement method of gas pressure in coal seam underground, the maximum gas pressure at this point is taken as the gas pressure at the same pressure measuring site. Therefore, the measured gas pressure of 8_2 coal seam in the protected area of Qidong coal mine of the third mining area is 1.9Mpa (elevation -589.3m) before the unexploited protective layer and the gas extraction.

Table 1. Actual construction parameters of pressure drill

Hole No.	Azimuth /°	Angle /°	Deep hole /m	Hole sealing length /m	Control the elevation /m	Control the depth /m	Gas pressure /MPa
1#	134	-35	20	15	-588.4	608.4	1.9
2#	254	-35	20	16.5	-589.3	609.3	1.8

4.1.2. Original Gas Content Determination In Coal Seam 8_2 of Protective Layer. The indirect method is used to determine the gas content in coal seam. First, the original gas pressure in coal seam should be measured in the underground or calculated according to the known law, and the coal porosity, adsorption constant and industrial analysis of coal after fresh coal sample is taken to the laboratory, and then the gas content in coal seam can be calculated according to Langmuir equation.

The calculation formula is:

$$X = \frac{a \cdot b \cdot P}{1 + b \cdot P} \cdot \frac{100 - A_{ad} - M_{ad}}{100} \cdot \frac{1}{1 + 0.31M_{ad}} + \frac{10F \cdot P}{\gamma} \quad (2)$$

Type: a, b—Adsorption constant, $a = 17.3428 \text{ cm}^3/\text{g}$, $b = 0.8769 \text{ MPa}^{-1}$;

P—Gas pressure, $P = 1.9 \text{ MPa}$;

M_{ad} —Moisture, $M_{ad} = 0.44\%$;

A_{ad} —Ash, $A_{ad} = 14.41\%$;

F—Porosity, $F = 2.92\%$;

γ —Apparent density, $\gamma = 1.33 \text{ t/m}^3$.

The above parameters were substituted into equation (2) and calculated that the original gas content of 8_2 coal seam in the protected area was $8.5379 \text{ m}^3/\text{t}$ before the unexploited protective layer.

At the same time, the DGC direct determination device was used to determine the gas content of 8_2 coal seam by direct method when the pressure borehole was measured and the pressure relief gas was drilled in the no.1 gas drainage roadway. The measured results are shown in table 2.

Table 2. List of measured gas content in coal seam

Coal seam	Hole No.	Control the elevation /m	Control the depth /m	Gas content m^3/t
82	44 group 2#	-568.2	588.2	9.74
	54 group 3#	-582.0	602.0	8.50
	54 group 4#	-575.2	595.2	8.56
	C1	-582.6	602.6	7.04
	C2	-611.0	631.0	7.97

To sum up, both indirect method and direct method were used to measure the gas content of the protected coal seam 8_2 in the test area from $7.04 \sim 9.74 \text{ m}^3/\text{t}$ before the protective layer and gas extraction.

4.2. Analysis On The Effect of Pressure Relief of The Protected Layer (8_2 coal seam) After Mining The Protective 7_{137} Working Face

4.2.1. Investigation of Angle and Range of Pressure Relief. Protection According to the relevant requirements of the regulations on coal and gas outburst prevention and control, the range of protective layer tendency protection shall be determined according to the theoretical pressure relief Angle. Average 7_{137} working face of coal seam dip Angle for 13° , theory of pressure relief Angle for $\delta_3 = \delta_4 = 75^\circ$. The theoretical protection range of coal seam 8_2 along the trend direction is shown in figure 1.

According to the calculation, the position of the upper and lower theoretical protection line of the coal seam 8_2 of the protected layer corresponds to the normal position of the air lane and machine lane of the protected layer face downward (internal fault) and upward (internal fault) 14.1 m , respectively, relative to the working face of the 7_{137} protective layer.

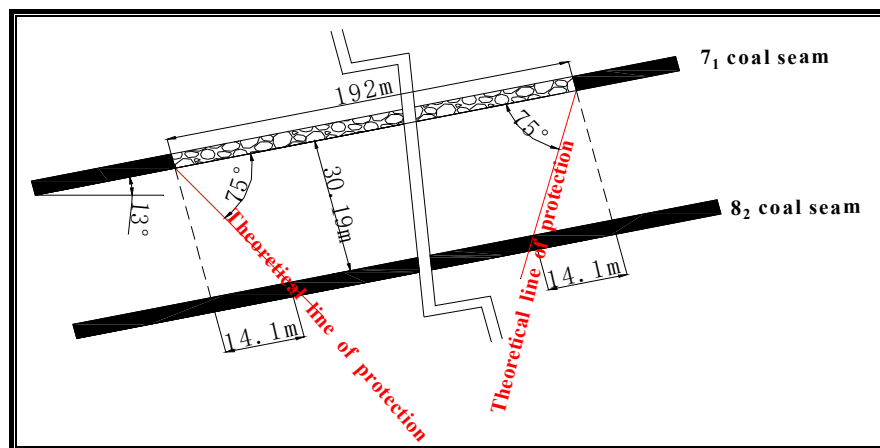


Figure 1. The range of theoretical protection of trend direction

According to article 51 of regulations on coal and gas outburst prevention and control and practical experience of mining protective layers at home and abroad, when the swelling deformation rate of the protected coal and gas outburst coal seam is more than 3‰, the protected coal seam can get effective

pressure relief protection. Field test point layout of coal seam inclination expansion deformation of the protected layer 8₂ is shown in Figure 2, and expansion deformation curve of relevant inspection borehole is shown in Figure 3~4.

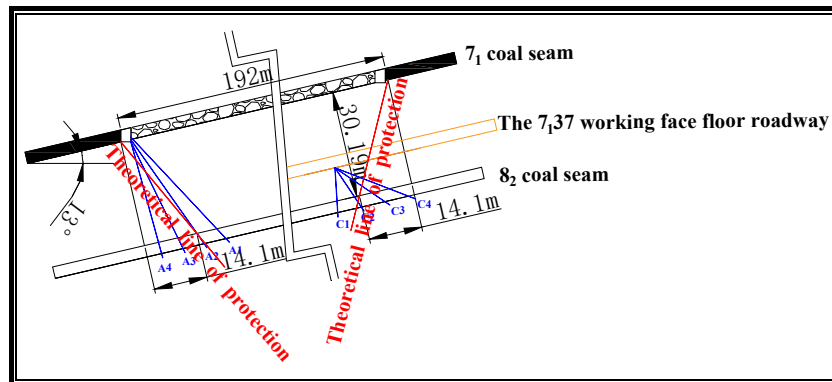


Figure 2. Profile of borehole layout for site investigation of inclined pressure relief Angle

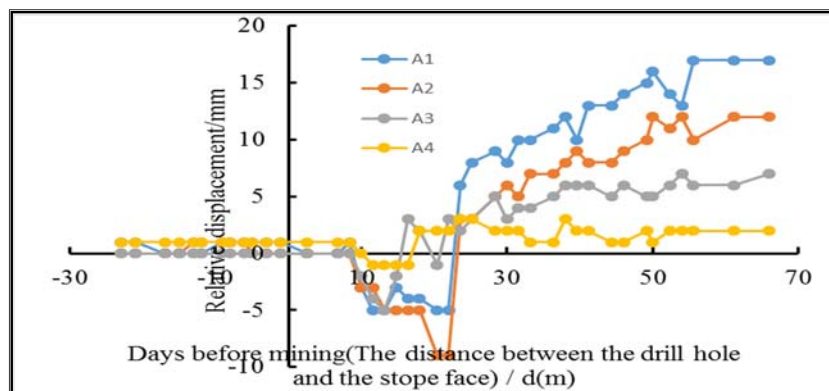


Figure 3. Expansion and deformation curves of borehole are investigated below the dip

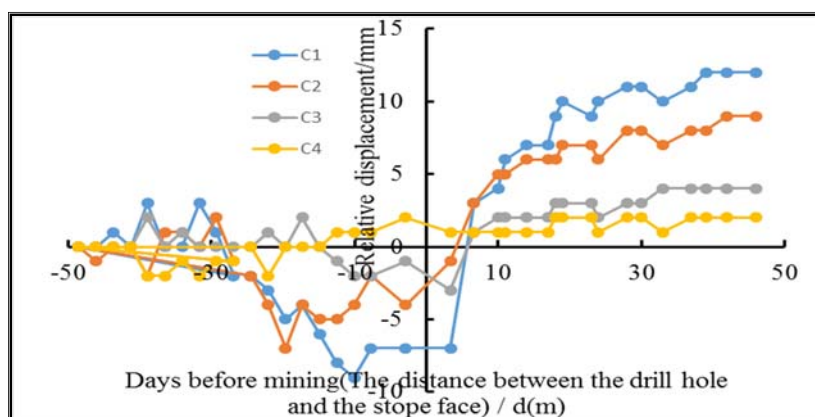


Figure 4. Shows the expansion and deformation curve of borehole above the inclination

According to the calculation, the relative deformation rates of the vertical coal seam directions corresponding to the boreholes A1, A2, C1 and C2 are all greater than 3‰. Obviously, the coal point positions in these boreholes are all within the effective pressure relief protection range. According to the investigation results of relative deformation of boreholes of A2, A3, C2 and C3, interpolation method was adopted and calculated through theoretical calculation. the pressure relief Angle of mining on 7137

working face to 8₂ coal seam inclined direction was $\delta_3=77^\circ$, $\delta_4=76^\circ$, and the actual position of the pressure relief protection line is shown in Figure 5.

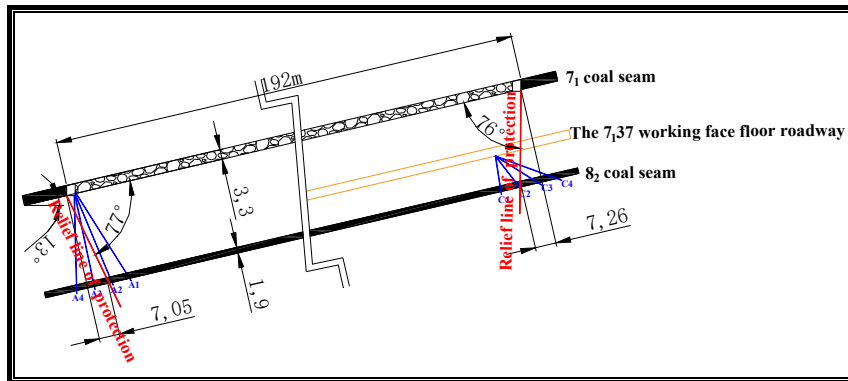


Figure 5. Profile of site investigation results of inclined pressure relief Angle

It can be seen from Figure 5 that, relative to the work face of the 7₁₃₇ protective layer, the position of the protective line above and below the inclined seam 8₂ of the protected layer corresponds to the normal position of the air lane and machine lane of the work face of the 7₁₃₇ protective layer, respectively 7.26m and 7.05m.

4.2.2. Investigation of Pressure Relief Angle and Range of Pressure Relief Protection. According to the relevant requirements of the regulations on coal and gas outburst prevention and control, the range of protective layer's strike shall be determined according to the theoretical pressure relief Angle. 7₁₃₇ working face of 7₁ the average Angle of coal seam for 13°, the theory of pressure relief Angle $\delta_5=56^\circ$. The theoretical protection range of coal seam 8₂ along the strike direction is shown in Figure 6.

According to the calculation, relative to the working face of the 7₁₃₇ protective layer, the position of the coal seam 8₂ trend line of theoretical pressure relief protection line of the protected layer is respectively within the position of the initial mining line and the normal line of stop mining line of the 7₁₃₇ working face at 20.36m.

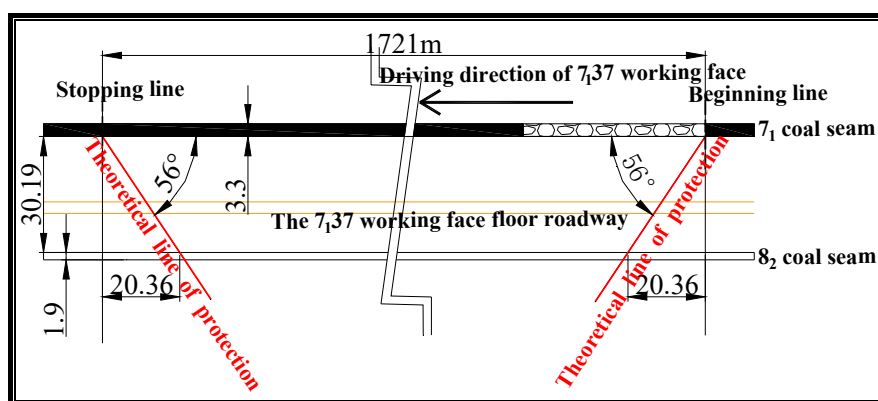


Figure 6. Range of theoretical protection of strike direction

According to article 51 of regulations on coal and gas outburst prevention and control and practical experience of mining protective layers at home and abroad, when the swelling deformation rate of the protected coal and gas outburst coal seam is more than 3%, the protected coal seam can get effective pressure relief protection. Field test point layout of coal seam towards expansion deformation of the

protected layer 8₂ is shown in Figure 7, and expansion deformation curve of relevant inspection borehole is shown in Figure 8~9.

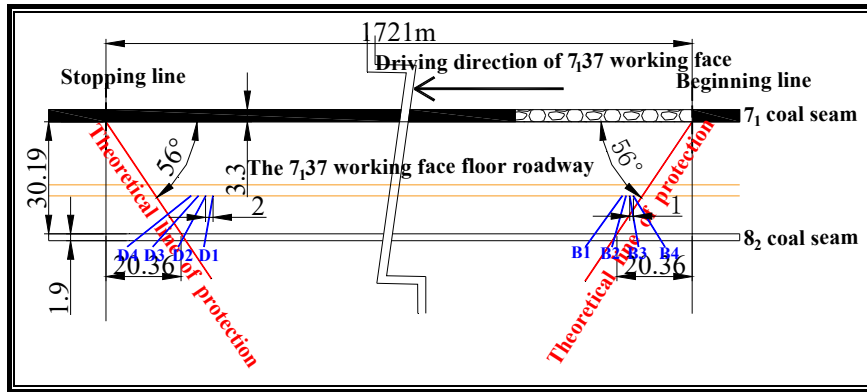


Figure 7. Profile of borehole layout for site investigation of pressure relief Angle

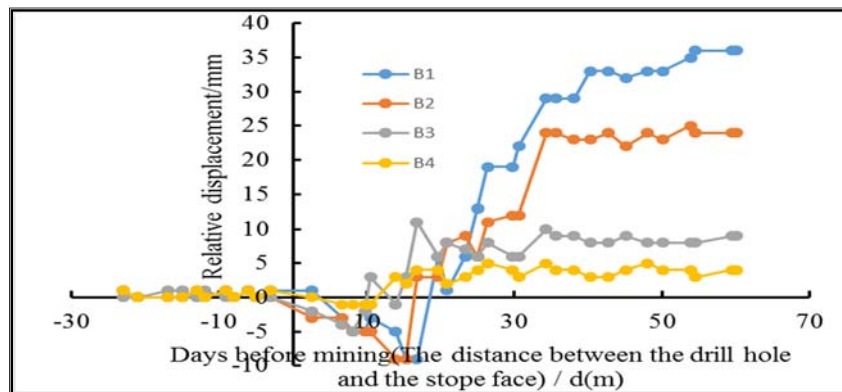


Figure 8. The expansion and deformation curve of borehole is investigated in trend

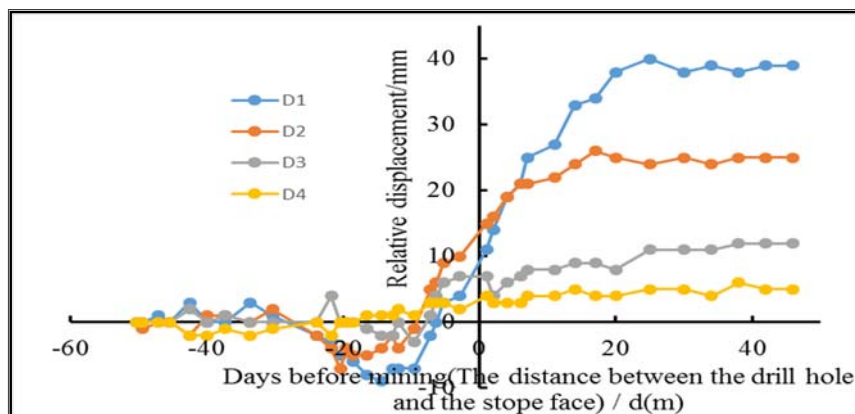


Figure 9. Expansion and deformation curve of borehole in trend investigation

According to the calculation, the relative deformation rates of the vertical coal seam directions corresponding to the boreholes B1, B2, D1 and D2 are all greater than 3%. Obviously, the coal point positions in these boreholes are all within the effective pressure relief protection range. According to the investigation results of relative deformation of boreholes of B1, B2, D1 and D2, interpolation method was adopted and calculated through theoretical calculation. the pressure relief Angle of mining on 7₁37

working face to 8_2 coal seam inclined direction was $\delta 5=57^\circ$, and the actual position of the pressure relief protection line is shown in Figure 10.

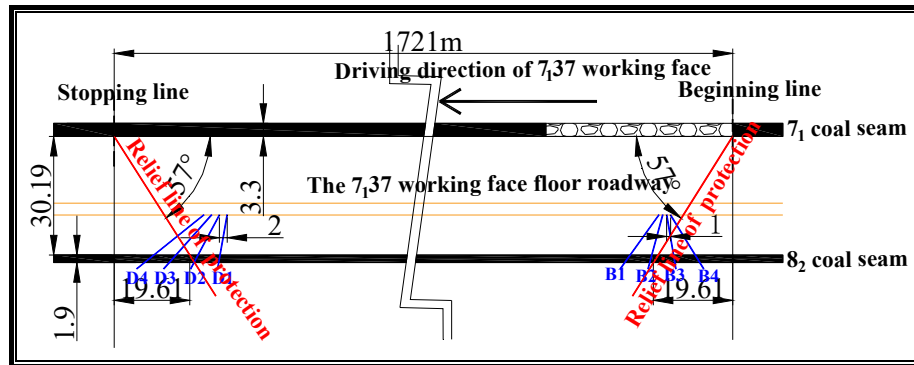


Figure 10. 7₁₃₇ working face mining section of the strike protection range of 8_2 coal seam

It can be seen from Figure 10 that, relative to the protective mining face of 7₁₃₇ protective layer, the position of the protective line at the cutting hole and stop-mining line of the 8_2 coal seam of the protected layer corresponds to the position of the normal line of the cutting hole and stop-mining line of the protective layer.

Combined with the survey of protective layer mining pressure relief protection Angle, after 7₁₃₇ protective coal face mining, underlying 8_2 coal seam in pressure relief Angle defined according to the actual trials are within the scope of protection, coal bed expansion deformation rate $> 3\%$, the basis for the prevention and control of coal and gas outburst regulations stipulated in article 40, mining of 7₁₃₇ working face of 8_2 coal seam underlying pressure relief protection effectively.

4.3. Analysis of The Effect of Regional Prevent Outburst Measures In The Coal Seam 8_2 of The Protected Layer After Mining of The Protective Working Face of 7₁₃₇ Protective Layer

Combined with the pressure relief gas extracted from 8_2 coal seam by drilling the protective layer, the cumulative gas extraction amount of 8_2 coal seam was calculated, and the evaluation of extraction standard of 8_2 coal seam was carried out. When the extraction and extraction of 8_2 coal seam reached the standard, then the regional outburst prevention measures were tested.

Residual gas content and residual gas pressure of coal seam 8_2 of protective layer were measured in the field, and the test results were shown in table 3.

Table 3. Statistical table of residual gas content and residual gas pressure measurement results of 8_2 coal seam

Hole No.	Control the elevation /m	residual gas content /m ³ /t	residual gas pressure /MPa
1#	-598.0	/	0.14
2#	-595.3	1.97	0
3#	-618.0	3.56	0.26
4#	-614.0	3.64	0.28
5#	-596.5	4.69	0.15
6#	-599.4	5.10	0.40

In 7₁₃₇ face pressure relief to protect the effective range, 8_2 coal seam in the residual gas pressure is 0.40 MPa, the residual gas content is 5.10 m³/t, meet the meet the prevention and control of coal and gas outburst regulations as stipulated in article 51 of the residual gas content is less than 0.74 MPa, the residual gas content is less than 8 m³/t request, therefore, according to the residual gas pressure, the

residual gas content test results, evaluate the efficacy of the outburst prevention measures of 8₂ coal seam area effectively.

5. Conclusion

By combining theoretical analysis and field observation, this paper makes an in-depth study on the effect of the upper protective layer mining of the close coal seam group in Qidong coal mine. The following conclusions are obtained:

(1) The feasibility of upper protective layer mining under this condition is analyzed theoretically. It is calculated that the maximum effective protective overhang of the underlying 8₂ coal seam is 36.64m in the mining of 7₁ coal seam. As the spacing between the protective face of the 7₁37 protective layer and the underlying 8₂ coal seam in the test area is 28~32m, less than the general maximum protective overhang, it is considered that the mining of 7₁ coal seam as the protective overhang of the underlying 8₂ coal seam is feasible in theory.

(2) In the process of downward mining, the mining of 7₁ coal seam has good pressure relief effect on the underlying 8₂ coal seam and can basically eliminate the outburst risk of 8₂ coal seam. However, considering that the local gas is still large, the outburst risk of the protected coal seam 8₂ should be completely eliminated in the mining process by further combining the pressure relief gas extraction.

(3) In this paper, after the protective layer mining, the evaluation of the extraction standard effect of the pressure relief gas extraction amount of the protective layer is insufficient; The effect of the stress concentration area formed by geological structure and mining disturbance on the protected layer is not fully considered. The above problems still need further study.

Acknowledgments

This work was financially supported by the national key research and development program of China (2017YFC0804206).

References

- [1] Mou Lin. Technology of water hazard control with protection layer for gassy coal seam. [J] Coal geology & exploration, 2015, 43 (05): 57-60.
- [2] Wu Gang. Study on the pressure relief mechanism of upper protective seam mining and gas extraction technology in close coal seams.[D]China university of mining and technology,2015.
- [3] Lu Mingxing. Pressure relief mechanism at upper protective layer mining in Liangzhuang coal mine and numerical simulation of protection scope.[J] Metal mine, 2015, (04): 7-11.
- [4] Cheng Yuan-ping ,Zhou De-yong, Yu Qi-xiang, Zhou Hong-xing, Wang Hai-feng. Research on extraction and emission Laws of gas for pressure-relief in protecting coal seams.[J] Journal of Mining & Safety Engineering, 2006, (01): 12-18.
- [5] Cheng Yuan-ping , Yu Qi-xiang. Application of safe and high-effieient exploitation system of coal and gas in coal seams.[J] Journal of China University of Mining & Technology, 2003, (05): 5-9.
- [6] Ma Hong-yu, Chen Yong, Zhang Shao-shuai,Gas drainage technology of floor strata boreholes in contiguous upper protective seams.[J] Coal Science and Technology, 2014, 42 (02): 47-49+53.
- [7] Wang Haifeng. The principle of pressure relief of subsurface coal body in stope and its application in gas extraction by pressure relief of protected layer [D]. China university of mining and technology, 2008.
- [8] Liu Zhen, Li Zenghua, Yang Yongliang, Tang Yibo, Ji Huaijun. Coal mining and gas treatment technology for protective layer above coal seam group with close outburst [J]. Coal science and technology, 2012, 40 (07): 49-53.
- [9] Wang Haifeng, Cheng Yuanping, Wu Dongmei, Liu Hongyong. Optimization of gas emission and gas extraction parameters of protective layer mining face at close range [J]. Journal of coal, 2010, 35 (04): 590-594.

- [10] Research on the prevention theory and key technologies of protective layer mining in hongling coal mine [D]. Liaoning university of engineering and technology, 2012.
- [11] Yu Bufan. Technical manual for coal mine gas disaster prevention and utilization (revised edition) [M]. Beijing: coal industry press, 2005.