International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

RESEARCHERID
THOMSON REUTERS

[Zhang *et al.*, 9(4): April, 2020]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

MONITORING THE IGNITION OF TECTONIC-COAL WITH ITS FACTOR ANALYSIS IN THE COAL MINE OF QIANJING, SHANXI PROVINCE, CHINA

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DOI: 10.5281/zenodo.3778560

ABSTRACT

This article presents the monitoring of tectonic-coal ignition with its factor analysis with taking on-site inspection and field work measurements in the case study of the coal mine of Qianjing, Shanxi Province, China. The results show that, when nitrogen injection control measures was in a side entry of the working face, the CO-concentration in the upper corner of the working face and in the return air was remaining at a stable level, at which moment the absolute value of CO-concentration was at the level of 0.031m^3/min. Especially when starting to weaken the equalized pressure ventilation system, the CO-concentration in the upper corner of the working face and in the return air was being lower than before, with the absolute CO-concentrationat 0.029m^3/min. The results indicate that the timely inspection, factor analysis, and prediction of tectonic-coal developing areas are effective measures to prevent the tectonic-coal ignition and CO gas emission in the case study. The study shall provide a new reference for monitoring the ignition of tectonic-coals in the similar coal mines in China or other countries.

KEYWORDS: Structural engineering, tectonic-coal, coal mine, working face, CO-concentration.

1. INTRODUCTION

Background

1.1 Study Area

The study area is selected at the coal mine of Qianjing (Figure 1) in Shanxi Province of China, which is located in the northwest of ShanyinCounty, within the administrative division of Yujing town, ShanyinCounty. It is about 32 km away from the North Tongpu Railway and Dayun Highway in the east and 5 km away from YujingTown in the southeast, so the traffic is convenient. After integratedwith local coal industries, it is adjacent to Shanxi Shanyin Golden Ocean Nanquanwan Coal Industry Co., Ltd. in the north, Shanxi ShanyinBaoshan-Yujing Coal Industry Co., Ltd. in the east, and Shanxi ShuozhouShanyin Golden Ocean Yuhuang Mountain Coal Industry Co., Ltd. in the west, but no adjacent mines in the south.

ISSN: 2277-9655
Impact Factor: 5.164
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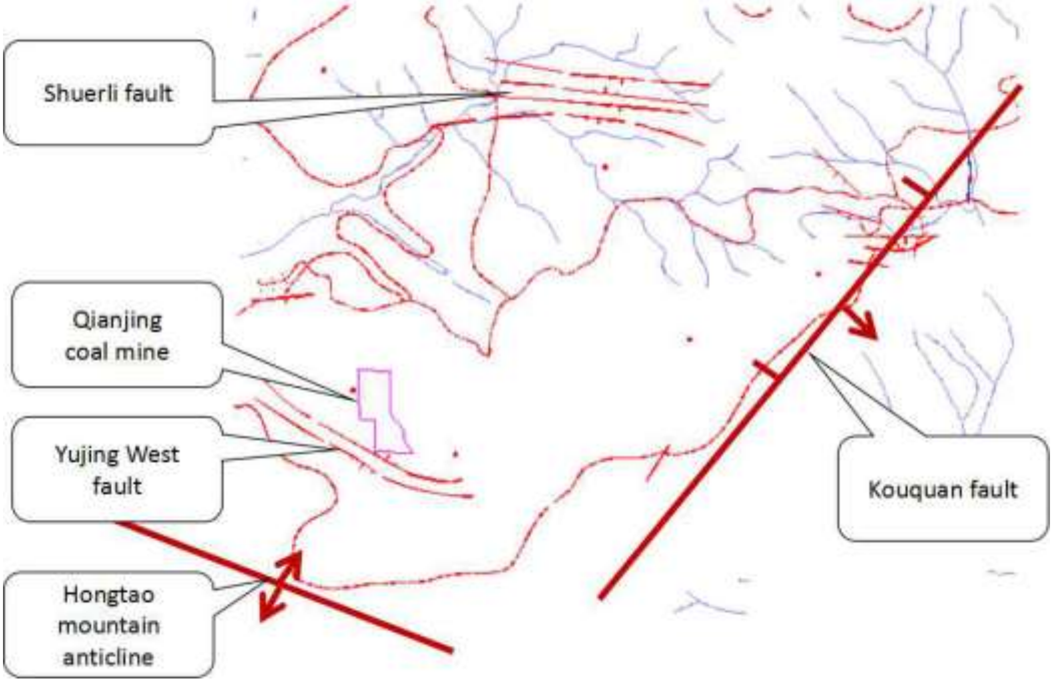

Figure 1: The structural outline map of Qianjing Coal Mine

1.2 Basic situation

This minefield is defined by 12 inflection points with an area of 4.5551km^2in the north-south length of about 3.471 km and east-west width of 2.408km. It is approved to mine the No. 4-11 coal seamsat a production capacity of 900,000 tons/year, between the mining elevations from 1,450m to 1,330m.

It is located in the hilly area on the north wing of Hongtao Mountain in the northern Shanxi, with ups and downs of terrain and developed gullies. The middle part of the minefield is high, but low in the north and south. The highest point is placed on Shijiatun ridge in the middle of the minefield, with an altitude of 1,617.20 m, while the lowest point is located in the gullies of the southeast in the minefield, with an altitude of 1,425.00 m and a relative difference of height at 192.20 m.

The minable coal seams in this mind field are No.4, No.9, and No.11, respectively, with a total of 76.64 million tons of resources/reserves, 45.39 million tons of designed resources/reserves, and 17.52 million tons of designed recoverable reserves (i.e., 720,000 tons of No. 4 coal seam, 4.42 million tons of No.9 coal seam, and 12.38 million tons of No. 11 coal seam). The service life of the mine is about 13.87 years. Among them, No. 11 coal seam is designed to be mined, which is the type of gas coal.

2. GEOLOGICAL CONDITIONS OF THE COAL MINE

The geological structure of this mind field is generally a fold-structure with a wide slow-steep and stratigraphic dip angle of 2 ~ 8°. NW-SE syncline to S1 was developed in the north middle-part of the mind field, while NW-SE syncline to S2 and S3 was developed in the west-south of the mind field. A normal fault was found in underground excavation in the northeast and middle part of the well field (Zhao, 1996). In the north of the mine field, a collapse column was found in the underground mining, where it was no magmatic rock intrusion in the mine field, and the geological structure of the mine field was simple (see Figure 2).

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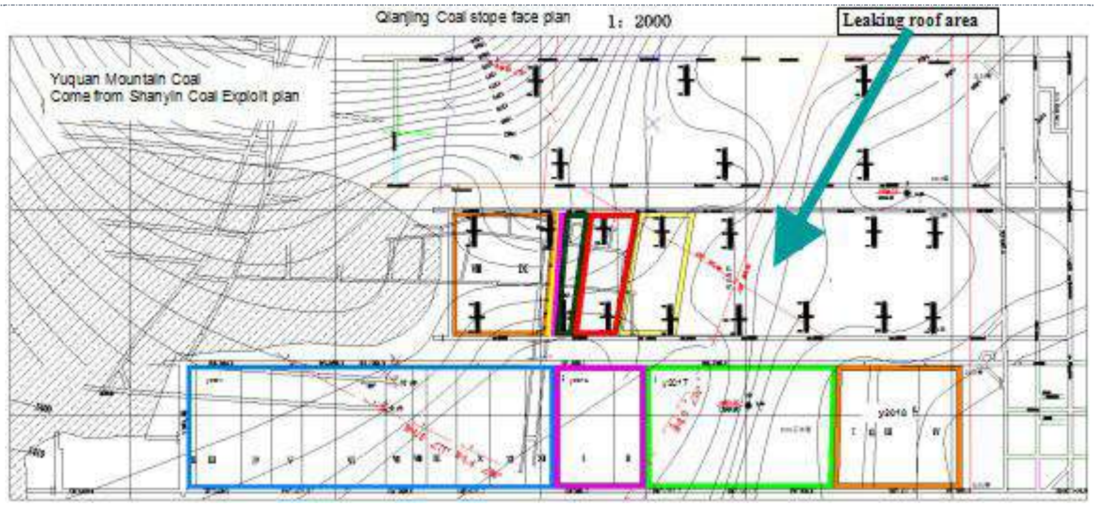

Figure 2: Plan for working face No. 8301 on the No. 11 coal seam

3. BASIC INFORMATION OF WORKING FACE ADOPTED

In the north of working face No. 8103, it is No. 8105 standby mining face; in the east, it is a belt roadway, track roadway and return wind roadway; in the west, it is a small kiln failure area with the No. 11 efflorescent oxygenized coal seam in Yuhuang mountain; and in the south, it is No. 8101 first mining face after recovery. The working surface is covered by the No. 9 efflorescent oxygenized coal seam, with the average interval between layers at 12 meters. The coal seam of the working face is stable and the dip angle of the coal seam is 1° -9 °, at the average of 5°.The coal thickness is 5.0-6.4 m, with the average thickness of 5.5 m. There are five layers of gangue in No. 11 coal seam, at the average thickness of gangue in 0.15m and the total thickness of 0.69m. A reverse fault with a strike of NE30 ° (dip of 70 ° shear) and a drop of 3m (from No. 2103 lane to 300m and from No. 5103 lane to 250m, with a fault fracture zone of 7.5m) is exposed in the No. 8103 working face, with an impact range of 50m. Another reverse fault with a strike NW60° drop of 1 m was exposed (No. 2103 lane mined to 190 m and No. 5103 lane to 330 m, with a fault fracture zone of 2.5 m), affecting an area of 140 m. The two groups of faults were expected to meet at 270 m in the middle part of the working face, which is prone to the roof leakage accidents.

The current No. 11 coal seam is being mined with one working face and two driving working faces, compared with the No. coal seam in another minefield. The first mechanical excavation team has excavated No. 5102 return airway, with a design length of 360 m, where 32 m has been excavated, while the excavation has been closed and stopped. The second mechanized excavation team has excavated No. 8105 the second cut, with a design length of 120 m, where 42 m has been excavated and stopped. Comprehensive mining is being mined in the No. 8103 working face, with a face length of 120 m, mining length of 510 m, and coal thickness of 5.5 m, while the head gateway mining is to 274 meters and the tail gateway mining is to 275 m.

4. ABNORMAL ANALYSIS OF CARBON MONOXIDE AND PREVENTIVE MEASURES

4.1 Carbon monoxide (CO) gas monitoring inNo. 8103 working face

CO (Carbon monoxide) overshoot occurs at the upper corner when passing the NW-trending fault on the working face of No. 8103, as the continuous monitoring changes are shown in the figures (see Figure 3 and Figure 4). It can be seen that CO overshoot coincides with the height of the passing fault, indicating that fault structural coal is the main area of ignition (He, 2004; Xu, 2014).

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Figure 3: A sample of tectonic-coal in Qianjing Coal Mine

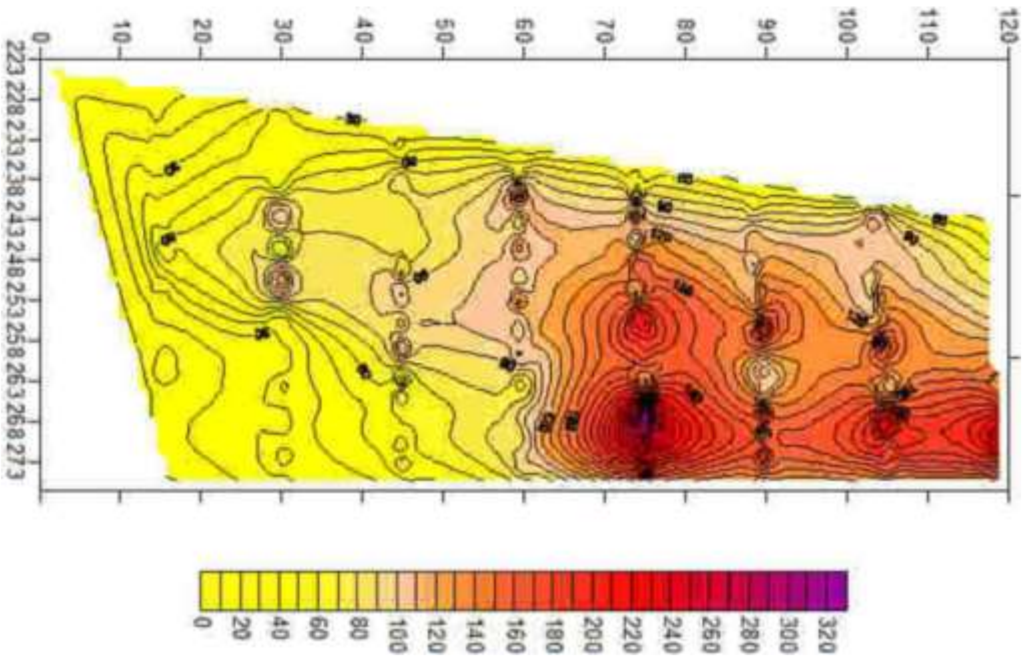

Figure 4: Plan of CO gas monitoring in the No. 8301 working face

4.2 Identifying ignition periods using fault tectonic coal samples

From the analysis and appraisal results (see Table 1 and Table 2) of the tectonic-coal samples in the No. 11 coal seam, there is a big difference from those of the normal coal samples. The tectonic coal has the characteristics of high volatile content, low ignition point, and low density. According to the underground sampling, these are some signs of fire-ignition in the structural developing area.

Table 1: Laboratory-analysis results of No. 11 coal-seam and tectonic-coal.

	Air-dry	dry	Dry-ash free	Received ash
Total moisture%	--	--	--	--
Moisture%	0.71	--	--	--
Ash %	12.20	12.29	--	--
Volatile-	61.47	61.91	70.58	--

matter %				
Fixed carbon %	25.62	25.80	29.42	--
Gross calorific value MJ/kg	--	--	--	--
Total sulfur %	2.67	2.69	--	--
Carbon %	--	--	--	--
Hydrogen %	--	--	--	--
Oxygen %	--	--	--	--
Nitrogen %	--	--	--	--
Phosphorous %	--	--	--	--
Chlorine %	--	--	--	--
Arsenic %	--	--	--	--
Fluorine %	--	--	--	--
Mercury %	--	--	--	--
Carbonate carbon dioxide %	--	--	--	--

Table 2: Comparison of laboratory-analysis results between No. 11 coal-seam and tectonic-coal.

	M ad	A d	Vd af	St-_d	Depending on the density	Fixed carbon	Oxygen intake	Colloidal index	Ignition temperat-ure	Spontaneous ignition
No.11 coal	2.3	28	38.6	2.26	1.42	80		47/8.5 Smooth shock type	400	natural
Tectonic coal	0.7	12	61.5	2.67	1.23	25.6	0.56	75/0 Smooth bevel type	330	natural

4.3 Thin-section microscopic identification of coal samples from fault tectonic-coal

From the microscopic identification of tectonic coal, it can be seen that tectonic coal has the characteristics of complete crystallization, hyphae development and easy to be fire (see Figure 5 and Figure 6). So some new findings can be summarized as below:

1) The coal seam of No. 8103working face is high in sulfur, and there are goose-like pyrite nodules and globular pyrite nodules with different grain sizes. Roadway ventilation accelerates pyrite nodules oxidation, if the local high-temperature area is formed in the structural zone,with the low-wind area of the tunnel and spontaneous combustion of the tectonic coal, resulting in abnormal CO emission;
2) During the mining period in the No. 8103 working face, the maximum air leakage reached $100m^3/min$, but no nitrogen injection was adopted to prevent fire extinguishing. If there were long-term oxygen supply and heat-storage conditions in the air leakage path to the working face, it led to the intensified oxidation of lost coal in the air leakage channel and abnormal CO emission existing in the upper corner and return air flow;
3) Because three longitudinal empty tunnels are being in the working face, if the roof of the working face were broken after a long-term working, the broken coal would be in full contact with the air for a long time. Meanwhile, the heat storage conditions would exist in the empty roadway, resulting in the occurrence of spontaneous combustion';
4) Detection of gob on top of coal seam can be made by GPR (general purpose of radar shown in Figure 7);
5) Tectonic coal can be found at the reverse fault of the No. 8303 working face in Wangping Coal Mine (see Figure 8).

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Impact Factor: 5.164
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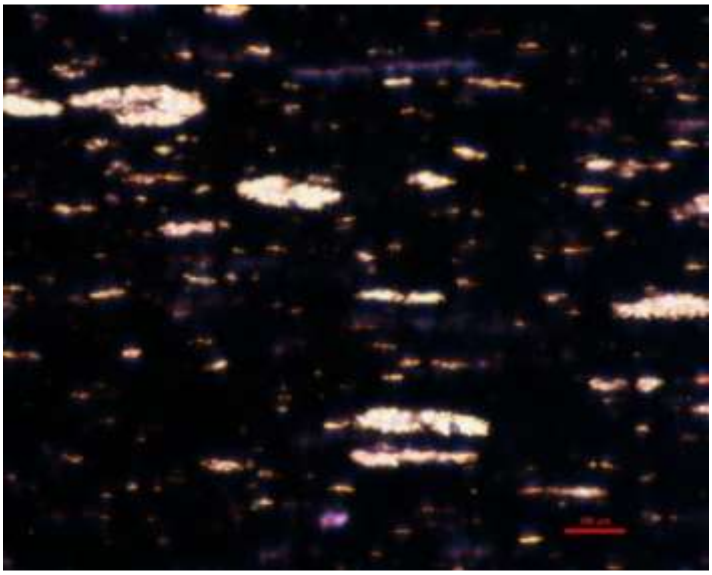

Figure 5: Microscopic identification result of thin sections of tectonic coal (vitrinite)

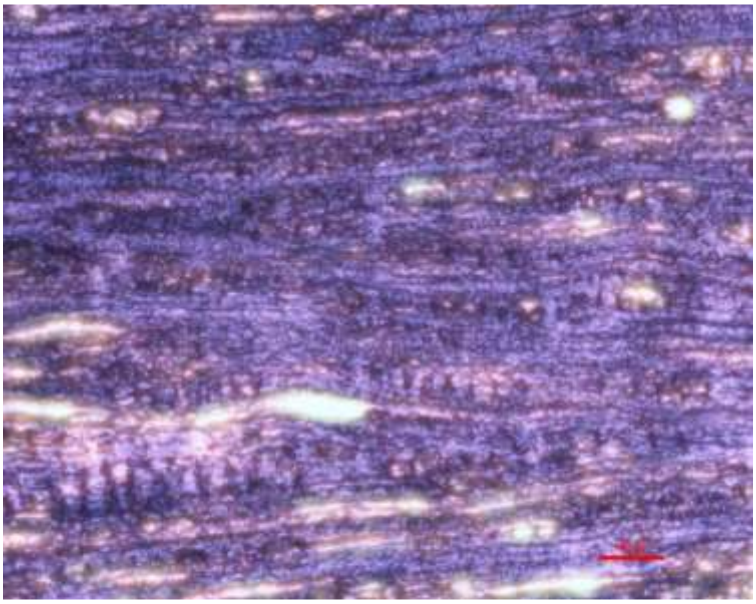

Figure 6: Microscopic identification result of thin sections of tectonic coal (with wooden structure)

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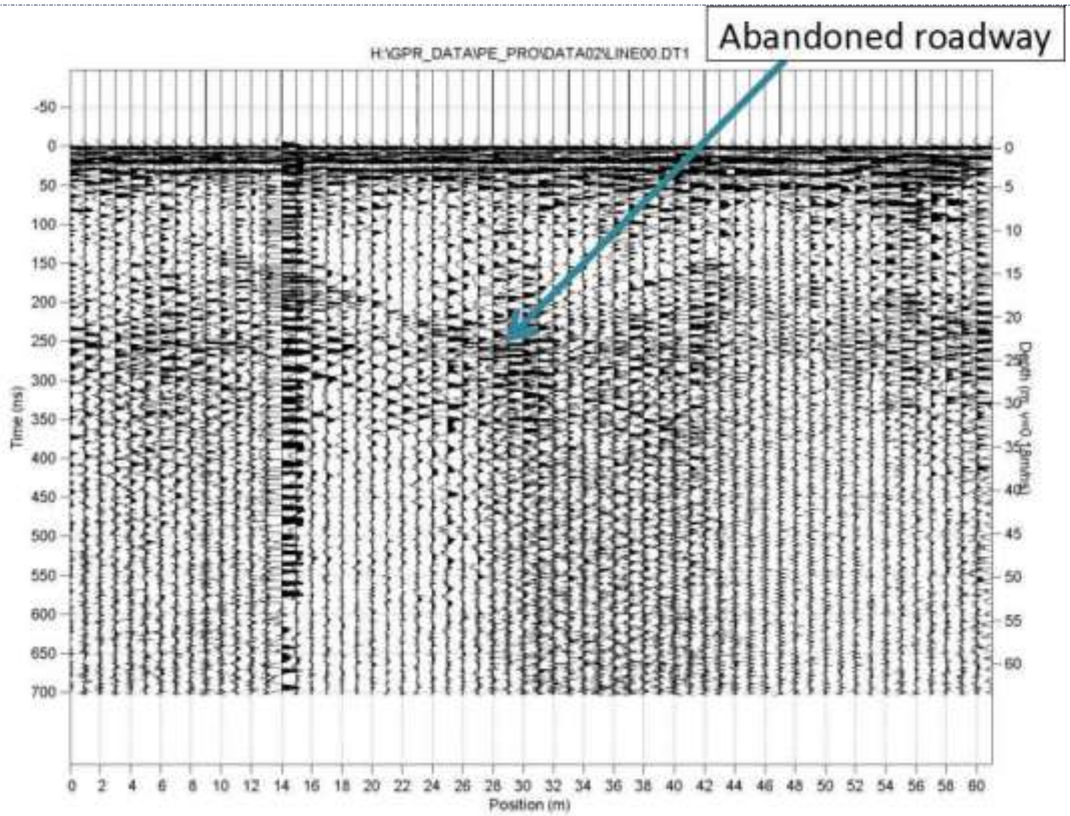

Figure 7: Tectonic coal is developed at the reverse fault of Wangping 8303 working face

Figure 8: Tectonic coal seen at the reverse fault of the No.8303 working face in Wangping.

4.4 A Case study

On July 12, 2019, after the implementation of nitrogen injection control measures in side entry of the working face, the concentration of CO in the upper corner of the working face was stabilized at 90-110ppm, and the concentration of CO in the return air was stabilized at around 50-60ppm, at which time the absolute amount of CO was 0.031m^3/min. After starting the weakly equalized pressure ventilation system on July 15, 2019, the

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concentration of CO at the upper corner of the working face was stabilized at around 10ppm, the maximum concentration of CO at the 64-79 support was 110ppm, and the concentration of CO in the return air was stabilized at around 40-50ppm, when the absolute amount of CO was reduced to 0.029m^3/min.

On-site gas inspection: On July 23, the second shift carried out on-site implementation on the No. 8103 working face, and the multi-functional gas detector was used to carry out a detailed gas inspection on the working face. The gas concentrations at various points are as shown in Table 3.

Table 3: A field inspection table for gas condition inthe No. 8103 working face

Gas-site	CO-concentration (ppm)
End of lane 8103	14
3-4# bracket	57
13# bracket	23-25
38# bracket	50
46# bracket	50
52# bracket	120
64# bracket	110
Upper corner	10
Return flow	52

The above results in Table 3 show that the 52-64# support area is the intersection area of two groups of faults, which is also the area with the highest CO concentration. After the normal use of the equal-pressure ventilation system in August, CO gas gradually decreased.

It is clear that the timely inspection, data analysis, forecast and prediction of tectonic coal developing areas are effective measures to be taken for preventing the tectonic coal ignition and CO gas emission in the coal mine of Qianjing.

4.5 Preventive measures

With the support of on-site inspection and the field work measurements, we suggested some key points of preventive measures as below:

1) Observing for geological structures and making comprehensive analysis for the conditions of heat temperature in the air leakage path and abnormal CO emission existing in the upper corner and return air flow, so as to predict any kinds of hidden dangers for coal ignition;
2) Formulating for some scientific, reasonable, and safely technical measures, and taking injection of nitrogen into go af to start weakening equalizing ventilation system;
3) Strengthening on site supervision and management to ensure that measures are in place;
4) Increasing the monitoring and assessment.

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5. CONCLUSION

In this study, we present the analysis for the reason of ignition in structural coal by taking on-site inspection and field work measurements in the case study of the coal mine of Qianjing, Shanxi Province, China.

In an implementation testing on July 12, 2019, when nitrogen injection control measures in a side entry of the working face, the concentration of CO in the upper corner of the working face was remaining stable at 90-110ppm, while the CO concentration in the return air was being fixed at the level around 50-60ppm, at which moment the absolute value of CO concentration was at the level of 0.031m^3/min. After starting to weaken the equalized pressure ventilation system on July 15, 2019, the CO concentration at the upper corner of the working face was being stable at the level around 10ppm, with the maximum CO-concentrationat the level of 110ppmin the place of No. 64 bracket, while the CO-concentration in the return air was keeping at around 40-50ppm, where the absolute amount of CO was 0.029m^3/min. On-site gas inspection on July 23, 2019 shows that the second on-site implementation for the No. 8103 working face, using the multi-functional gas detector to carry out detailed gas inspection with the similar results. These results indicate that the timely inspection, data analysis, and prediction of tectonic-coal developing areas are effective measures to prevent the tectonic coal ignition and CO gas emission in the coal mine of Qianjing. The methods can also provide a reference for the similar coal mines in China or other countries.

6. ACKNOWLEDGEMENTS

The authors thank the laboratory results of coal and tectonic coal samples analyzed by the China national coal quality supervision and testing center.

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